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[**NOTE TO READERS:** Effective 1 October, the processing indicators appearing in brackets at the start of each item will be changed. All new indicators will begin with "FBIS" to make the material more easily identifiable. Some will also indicate whether the item has been translated from the vernacular or transcribed from English.]

Advanced Materials

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AIST Postpones Interim Evaluation of 300kW Ceramics Gas Turbine

94FE0775A Tokyo KAGAKU KOGYO NIPPO in Japanese 16 Jun 94 p 12

[Text] Because of a shortage of data, the Agency of Industrial Science and Technology (AIST), MITI, has decided to postpone interim evaluation of a 300-kW ceramic gas turbine (CGT) that has been under development for a year. Instead, AIST will spend the rest of the current fiscal year collecting the necessary data. According to the initial plan, AIST was to perform interim evaluation in March 1994 and make a decision of "go" or "no go" for the development of a pilot turbine in the second half of 1994. Today, however, because of the delay in the development of the CGT prior to the development of the pilot turbine, the CGT has not been test-operated for more than 10 minutes, far short of the cumulative 20 hours required for evaluation. Nevertheless, the effort will be made to continue the development, because the high-precision production technology elements for complex-shaped ceramic components have already been developed beyond their targeted levels. Those decisions are expected to be made at a 16 June 1994 meeting of the evaluation sub-committee and at an early July meeting of the evaluation committee of the Industrial Technology Council.

Small gas turbines of the 300 kW level have been unable to generate a thermal efficiency of more than 20 percent because of the difficulty in cooling the rotor. AIST's project aims at achieving a thermal efficiency of more than 42 percent by incorporating ceramic components to attain a turbine inlet gas temperature of 1,350°C without cooling. Such gas turbines are expected to be used in co-generation and portable generation systems.

In the project, three uniquely different types of turbines are being developed simultaneously. Ishikawajima-Harima Heavy Industries Co., Ltd., is in charge of the development of CGT 301 and CGT 302, which have been test-operated for 7 and more than 10 minutes, respectively. Yanmar Diesel Engine Co., Ltd., is developing CGT 303, which has been test-operated for many hours without any heat exchanger. However, for the interim evaluation, each of the turbines needs to be run for a cumulative time of approximately 20 hours. Therefore, the evaluation was postponed for a year or so to gain time for further test runs.

The development project is divided into three phases, whose targets are:

(1) a metal turbine with an inlet temperature of 900°C;

(2) a basic model CGT with a turbine inlet temperature of 1,200°C;

(3) a pilot CGT with an inlet temperature of 1,350°C.

Today, the 1,200°C CGT of the second phase needs more test runs. According to a spokesperson, temperature measurement itself becomes difficult when the turbine inlet gas temperature reaches 1,200°C. Test runs are conducted extremely carefully because the ceramic components are expensive. It is difficult to manufacture complex-shaped ceramic components with high precision because ceramics tend to undergo shrinkage by 20 percent in length and 50 percent in volume, and because ceramic components tolerate the presence of little or no internal flaws. However, individual ceramic components have already developed to levels that exceed the project's targets. Thus, the project will proceed by making improvements in the system through test runs.

GIRI Nagoya Fabricates Above 99% Density Alumina

94FE0775B Tokyo KAGAKU KOGYO NIPPO in Japanese 23 Jun 94 p 8

[FBIS Translated Text] The Government Industrial Research Institute (GIRI), Nagoya, has successfully used the vacuum sintering method to produce a high-density alumina ceramic material with a relative density of more than 99 percent. In the vacuum sintering method, gases that remain in internal air pockets in a mold are evacuated, so individual pores can be eliminated. Therefore, the method is expected to be used in place of the capsule-free HIP method to commercially produce ceramic components. GIRI, Nagoya, plans to work on the optimization of calcination conditions and the examination of the ceramic's properties, including mechanical properties.

The Fabrication Technology Laboratory of the Ceramic Application Department, GIRI, Nagoya, has been studying the molding technology for ceramics. Its achievements thus far include the preparation of highly concentrated, highly dispersed slurries (having a water content of 23 percent by weight) of high-purity submicron alumina powder and the preparation of homogeneous, high-density molds by the vacuum, excess-pressure cast-molding method, as well as high-strength alumina ceramics by normal-pressure sintering.

The Laboratory had also studied various production methods of ceramic components, including high-strength, optically transparent alumina ceramics, by the capsule-free HIP method.

Each of these production methods has advantages and disadvantages. In particular, the capsule-free HIP method, despite its ability to sinter a mold into a denser ceramic material at a temperature lower than that for the normal-pressure sintering method, is not suitable for commercially sintering ceramic components because the method cannot handle large components without a large scale device and a high operating cost.

Under those circumstances, GIRI, Nagoya, had embarked on the development of high-purity alumina ceramics by the vacuum sintering method, which had been deemed more suitable for commercialization. A

porous resin cast was used to carry out vacuum cast-molding, and a mold was tentatively sintered at 800°C. At that stage, the material had a relative density of 62.5 percent. However, the group confirmed that the density increased to more than 99 percent after sintering at 1,250°C and to 99.7 percent after sintering at 1,350°C.

The vacuum sintering method is more practical than the capsule-free HIP method. The group plans to establish optimal production conditions and further study the properties of the ceramics.

Tohoku U, GIRI Tohoku Develops Ceramics Particle Dispersed TiAl Intermetallic Compound, Applicable for Spaceplane

94FE0775C Tokyo NIKKAN KOGYO SHIMBUN in Japanese 23 Jun 94 p 7

[Text] The research group led by Chief Researcher Hitoshi Hashimoto, of the Metal Section of the Government Industrial Research Institute (GIRI) (Director, Mr. Masatoshi Ono), Tohoku, of the Agency of Industrial Science and Technology, and Professor Ryuzo Watanabe at the Department of Engineering, Tohoku University, have synthesized a ceramic particle-dispersed titanium-aluminum intermetallic compound. The group used the mechanical alloying (MA) method to disperse ceramic micro-particles with a high melting point in the compound, so its heat resistance was improved in addition to being lightweight and having the high degree of hardness normally seen in titanium-aluminum alloys. The new compound is expected to be applied to structural materials that are lightweight and are required to be strong at high temperatures, such as fuselages for airplanes and spaceplanes.

An intermetallic compound is an alloy in which two or more metallic elements form a compound at a certain ratio. Unlike alloys in which elements are blended at an arbitrary ratio, or one-element metals, intermetallic compounds are considered to be one group of functional materials which include shape-memory alloys, superconductors, and hydrogen-occluded alloys.

The new intermetallic compound developed by the group consists of three elements: titanium, aluminum, and boron. The hot isostatic pressing process, a type of powder metallurgical method, was used for producing the compound. Actually, alloy powder consisting of titanium, aluminum, and boron was synthesized by means of ball-milling with chrome balls in an atmosphere of an inert (argon) gas. Subsequently, the alloy powder was pressed in a press mold and sintered at 1,400°C.

As a result, titanium boride particles ranging in size from several tens to several hundred nm were precipitated in the titanium-aluminum intermetallic compound, which withstood heat at 800°C. The group also confirmed that the intermetallic compound showed a Vickers hardness value of approximately 800, approximately twice that of a titanium-aluminum intermetallic compound containing no titanium boride. The tensile strength of the new compound was known to be proportional to the time of synthesis for the alloy powder. According to Researcher Hashimoto, the addition of boron "appeared to have alleviated the brittleness of the material."

The newly developed intermetallic compound is a material reinforced with dispersed particles and not only weighs less with its specific gravity being 3.8—one-half that of a superalloy—but also has better heat resistance than duralmin because of the dense structure with dispersed micro-fine ceramic particles.

If implemented, the compound is expected to be used in wide-ranging fields, including turbine-engine stators, gasoline-engine exhaust valves, and airplane fuselages. The group plans to further test the hardness and tensile strength of the intermetallic compound at high temperatures.

Kyocera Develops Ultra Heat Resistance SiN Ceramics for Ceramic Gas Turbine Rotor

94FE0775D Tokyo NIKKAN KOGYO SHIMBUN in Japanese 23 Jun 94 p 17

[FBIS Translated Text] Kyocera Corp. (Kyocera) has developed an ultra-heat-resistant silicon-nitride ceramic capable of maintaining a high strength of 660 MPa at as high a temperature as 1,350°C. Using the ceramic material, Kyocera also produced a rotor for gas turbines, which was confirmed to be suitable for commercial application with a continuous, 1,000-hour test run. The ceramic rotor was found to easily meet the target specifications established by the New Energy Development Organization (NEDO), spurring the practical implementation of the next-generation gas turbines. In 1994, Kyocera plans to supply the rotor to Yanmar Diesel Engine Co., Ltd., and Kawasaki Heavy Industries, Ltd., for evaluation.

The new ceramic material developed by Kyocera was derived from its previous silicon-nitride product, "SN-253," after the composition and the sintering process were modified. In other words, using a sintering aid based on rare earth metal oxides, the binder interstitial phase to bind silicon-nitride grains was made more heat resistant. In addition, baking conditions, such as time and temperature, were skillfully controlled to create a homogeneous and dense micro-structure that became the base for excellent heat resistance and high strength.

Kyocera obtained a high strength of 660 MPa for the 300-kW gas-turbine rotor when it was tested in a continuous run of 1,000 hours at 1,350°C, and a pre-oxidation strength of 580 MPa in an instantaneous fracture test at 1,500°C. The rotor's Weibull constant, an index for the non-uniformity in strength, was also found to be 28, which was excellent. Based on those test results and its own estimate of future mass production and cost reduction, Kyocera established a production technology—involving casting, press-molding, and the atmosphere calcination method—for large, complex-shaped products.

The gas turbine was expected to be the next-generation power source because of its compact size, light weight, and low pollution production. However, its efficiency in converting heat to power was lower than 30 percent, and it consumed a large quantity of fuel. In order to increase the heat efficiency, the turbine inlet temperature needed to be higher, and the rotor, which is operated at a high speed of 76,000 rpm, needed to be more highly heat-resistant. A thermal efficiency of 42 percent had been established by NEDO as the development target for the next-generation 300-kW gas turbine. In order to achieve that thermal efficiency, the inlet temperature was required to be 1,350°C. Prior to the new development by Kyocera, the maximum tolerable inlet temperature had been 1,000°C for metallic rotors and 1,200°C for ceramic rotors.

JFCC Develops New Measurement Method for Fine Ceramics Residual Stress

94FE0775E Tokyo NIKKAN KOGYO SHIMBUN in Japanese 24 Jun 94 p 7

[FBIS Translated Text] A new method for measuring internal stress (residual stress) in fine ceramics has been developed by the Japan Fine Ceramics Center (JFCC). JFCC applied the low-angle incident X-ray method to measure a wide range of strain (lattice strain) in the approximately one-micron-thick surface layer to a depth of several tens of microns. Thus, the internal stress, which had been obtained as an average value, can now be determined as a function of the depth for accurate analysis. In addition, the method permits non-destructive evaluation of the complex state of internal stress on the surface. The method is applicable to not only single-phase materials, but also poly-phase materials, thin films, and functionally gradient materials.

Thus, the method is promising as an effective evaluation technique for product development. When ceramic components made by molding and sintering powder raw-materials undergo a finishing process involving mechanical fabrication, such as grinding, the stresses generated by heat treatment and grinding tend to be accumulated within the ceramic materials. These stresses, along with the composition, structure, and flaws of the materials, significantly affect the strength and functionality of finished products. Therefore, it is one of the key points in material development to be able to evaluate and control the stresses. One X-ray stress measurement method, called the "sine-square-psi method," has been used in the majority of stress analysis cases. By this method, one can obtain only an average stress value at a depth of several tens to several hundreds of microns from the surface.

But a new problem emerged that could not be solved by that method. In the fabrication of an ultra-precision component, the extremely shallow region in the vicinity of the area of fabrication played an important role in the material's stability. Also, breaks in the integration pattern of a super-LSI were closely related to a localized inner stress generated at the time of the vapor deposition of the pattern. Thus, it became necessary to develop a tool with which one could evaluate precisely those inner stresses on the surface and local regions of ceramic materials. Researcher Yoshihisa Sakaida and Chief Researcher Shintaro Harada at JFCC, with the cooperation of Professor Keisuke Tanaka at Nagoya University, developed the new method with which measurements were made successfully.

The new method's key to success was to have X-rays incident on a target object at an extremely low angle. When a low incident angle is used, one can measure internal stresses in shallow regions. In addition, by changing the angle, it is possible to determine stress distribution in the depth's direction. The group used silicon nitride in experiments and found that the internal stress due to grinding showed a maximum compression stress of approximately 2,000 MPa near the surface. Also, the stress value decreased sharply with the depth, eventually reaching zero. Recently, surface improvement technologies, including nanometer-level ultra-precision surface finishing and coating, have been actively pursued. The new stress measurement method can be applied not only to this field, but also to non-destructive measurements involving thin films and functionally gradient materials. Furthermore, the method is expected to be a valuable tool for evaluating carbon dioxide separation membranes and synergy ceramics, both of which are now being developed under national government projects.

High Efficiency Fabrication Technology for High Purity Magnesia From Dolomite

94FE0775F Tokyo KAGAKU KOGYO NIPPO in Japanese 27 Jun 94 p 12

[FBIS Translated Text] Professor Tadashi Nishino's group at the Musashi Institute of Technology has successfully developed, from dolomite, a high-efficiency production technology for high-purity magnesia (magnesium oxide) that would be used as a raw material for electronic and functional ceramic materials. The technology involves the separation of high-purity magnesia and ultra-micro calcium oxide grains after dolomite is treated with a strongly acidic ion-exchange resin. This technology achieves the successful utilization of dolomite resources and the separation and production of two components. Because of its usefulness as an industrial technology in terms of cost, process, and product quality, the technology is expected to be implemented soon to replace the existing method of treating sea water to obtain high-purity magnesia.

The production method developed by Professor Nishino's group for high-purity magnesia and ultra-micro calcium oxide grains consists of the dissolution of dolomite and separation with a strongly acidic ion-exchange resin (H-R resin). Professor Nishino had already developed several technologies involving the H-R resin: the dissolution of kidney stones, the treatment by dissolution of wastes that are only slightly soluble, and a new

method for measuring the hydration heat for cement. This time he applied the same technology for material production.

Specifically, lumps of dolomite were directly calcined and added to water. The dolomite lumps were dispersed finely by the heat generated when the calcium oxide in dolomite was converted into the hydroxide in water. When the ion-exchange resin was added to the dispersion, the resin combined selectively with calcium. The resin-bound calcium was separated to become high-purity, ultra-micro calcium oxide grains. At the same time, high-purity magnesia was obtained from the remaining solution. The ion-exchange resin could be regenerated with a 10-percent solution of hydrochloric acid.

High-purity magnesia is used to produce alkaline fireproof materials, drugs, catalysts, fine ceramics and fillers for functional plastics. The existing production method for high-purity magnesia is to recover magnesium, contained in sea water at an ultra-micro concentration of 0.2 percent, in the form of magnesium hydroxide with the aid of lime, followed by the drying of the magnesium hydroxide. The method has a problem of boron contamination, in addition to a low yield. On the other hand, the raw material dolomite, with its magnesium content at 19 to 20 percent, is abundantly distributed all over the world, although there has been no method of separating magnesium from dolomite. Crushed dolomite has been used only for laying foundations for roads and buildings.

With Professor Nishino's group's new method, dolomite will be used more meaningfully with the high-efficiency production of high-purity magnesia and ultra-micro calcium oxide grains. Thus, the method is highly promising as a replacement for the existing method. In addition, the products made with the new method appear to present advantages in quality and characteristics. Thus, potential applications of high-purity magnesia include various electronic materials, laser-related materials, lenses for artificial satellite and infrared transmitters, with the last two taking advantage of the optical transmissivity of the magnesia. Also, ultra-micro calcium oxide grains may be used to produce functional ceramics, such as biologically compatible materials, including hydroxy apatite and new cement-based materials.

JFCA's Study Concludes Fine Ceramics Most Appropriate for Energy Conservation Purposes

94FE0776E Tokyo KAGAKU KOGYO NIPPO in Japanese 30 Jun 94 p 12

[FBIS Translated Text] The Japan Fine Ceramics Association (JFCA) compiled a survey report on the effects of fine ceramics when adopted for thermal engines and on energy conservation, thermal efficiency improvement, and global environmental load reduction. The report analyzes the current status of R&D through commercialization of fine ceramics in gas turbines, automobile engine components, and thermal engine combustion catalysts. The report also discusses technical problems to be overcome for expanding applications in each application field. According to the report, fine ceramics are regarded as promising materials that can solve energy conservation problems. The coordinated efforts by the industrial, academic and governmental sectors is said to be the key for the future implementation of fine ceramics.

The "Survey Report Concerning Environmental Load Reduction by Adopting Fine Ceramics to Thermal Engines" was compiled by JFCA on consignment from the Japan Machine Industry Federation.

Recently, the global environment, particularly the global warming problem, has become a worldwide concern. One of the suggested measures to deal with the problem is to improve the efficiencies of thermal engines.

Fine ceramics with excellent heat, corrosion and wear resistance are regarded as the revolutionary materials that can contribute to the preservation of the global environment. The survey described in the report was the first attempt ever to quantitatively analyze the relationship of fine ceramics to thermal engines by specifically suggesting appropriate components.

In the report, the current status of such environmental problems related to thermal engines as air pollution, global warming trend, and acid rain, is discussed. The report examines combustion technologies involved in thermal engines with respect to individual specific components, including external combustion, internal combustion, and composite engines. Furthermore, the report discusses the possibility of new combustion technologies utilizing ceramics.

The report concludes that the development of technologies of applying fine ceramics to thermal engines will be one of the key technologies for quickly establishing the global environment preservation and energy conservation technologies. Based on the conclusion, the report proposes major R&D topics for the future as follows.

Specific topics are:

(1) fabrication technology for fine ceramic materials and components;

(2) evaluation technology;

(3) design technology;

(4) finishing and inspection technology.

The report adds that, for using ceramics for a combustion (oxidation) catalyst, it will be necessary to list topics that are mutually related to component devices, operation control, and systems, in addition to the topics of catalytic performance improvement and catalytic durability improvement.

GIRI Nagoya Develops NbAl High Melting Point Compound by Plasma Activating Sintering Method

94FE0776A Tokyo KAGAKU KOGYO NIPPO in Japanese 27 Jun 94 p 8

[FBIS Translated Text] The Government Industrial Research Institute (GIRI), Nagoya, has developed a

high-melting niobium-aluminum intermetallic compound with the plasma activation sintering (PAS) method. The compound was found to have a relative density of 99 percent and a Vickers hardness value of 850-880 kgf/mm^2. GIRI, Nagoya, had already developed a high-specific-strength titanium-aluminum intermetallic compound by the PAS method, and the newly developed niobium-aluminum composite ceramic material was made in a similar fashion. Currently, the group is test-producing and evaluating 30mm-diameter disks of this intermetallic compound. The group plans to develop a near-net technology for the material soon. The PAS method is a new powder fabrication technology in which an input of electrical energy is made in pressed powder grain boundaries to initiate quicker and lower-temperature sintering than any of the previous sintering methods (including hot press, HIP, and atmosphere reactor) by means of the effective application of high energy of instantaneously generated discharge plasma. The method's advantages include ease of handling, high-speed sintering, and energy conservation. In particular, the method is highly reproducible when applied to metallic powders. GIRI, Nagoya, had already used the PAS technology to produce a high-specific-strength titanium-aluminum intermetallic compound with a high relative density and a high Vickers hardness value. This time, the group was able to use the PAS method to develop the similar, high-melting niobium-aluminum intermetallic compound.

Hitachi Metals Develops New Heat Resistance, Thin Cast Steel for Auto Exhaust Gas Parts

94FE0776B Tokyo KAGAKU KOGYO NIPPO in Japanese 28 Jun 94 p 8

[FBIS Translated Text] Hitachi Metals, Ltd. (Hitachi Metals), has developed a new heat-resistant cast steel NSHR-A3 (Development Number) that can withstand temperatures exceeding 1,000°C and that will be used in the production of automobile exhaust-system components. Regulations concerning auto exhaust-gas are being tightened everywhere, particularly in the United States, and, as a result, it has become urgent to reduce emissions (waste generated by incomplete combustion in an engine), shorten the time for activation of the catalyst, and improve the heat resistance and reduce the gauge of exhaust system components. The newly developed material, which is austenite-based, is capable of withstanding temperatures higher than 950°C and can be made into an average gauge of 2.5mm, both of which had been the limits for ferrite-based materials. Hitachi Metals also developed a new casting method for the heat-resistant cast steel, which had already been produced commercially for exhaust manifolds. Thus, Hitachi Metals plans to aggressively deal with the needs of auto makers, all the while watching closely the regulation-tightening trend.

The composition of NSHR-A3 is as follows: carbon (C), 0.4 percent; chrome (Cr), 20 percent; nickel (Ni), 10 percent; and tungsten (W), 3.0 percent. Hitachi Metals had previously developed such heat-resistant cast steel materials as the ferrite-based NSHR-F5 and the niobium-added, ferrite-based NSHR-F5N, both of which had been resistant to temperatures of up to only 950°C.

In order to cope with the tightened exhaust-gas regulations and fuel-cost reductions, emissions must be reduced. In order to reduce the emissions, it is necessary that exhaust-system components be able to momentarily withstand heat with temperatures above 1,000°C. The newly developed material demonstrated heat resistance that easily exceeded that requirement, which makes it possible to reduce emissions by 20-30 percent from the current level.

Along with the emissions reduction, it is also important to be able to shorten the time it takes for the catalyst to be activated. Since the catalyst is activated at temperatures above 300°C, it is necessary to send exhaust gas from the manifold as soon as possible. However, if the manifold is made in a thick gauge, some time is necessary to heat the manifold itself. It had been difficult to make a thin-gauge manifold, despite its satisfactory heat resistance, because of a potential problem of generating cracks due to the difference in the degrees of expansion and contraction between the oxidation film and the material of construction. With the new material, the manifold can be made with a gauge of 2.0mm at minimum and 2.5mm as an average.

The casting method was developed with self-hardening sand for making casts. In the previous iron casting method, water was required to compress sand. However, the cooling process began too soon to successfully shape thin-gauge parts. The self-hardening sand can withstand temperatures as high as 1,600°C, one of the molding conditions for steel casting.

The new steel has already been made into exhaust manifolds for racing cars. In the future, Hitachi Metals plan to use the new material to manufacture catalyst cases and turbine cases.

GIRI Tohoku Research on Ferroelectric Thin Films, Applicable for Electronic Devices

94FE0776C Tokyo NIKKAN KOGYO SHIMBUN in Japanese 29 Jun 94 p 7

[FBIS Translated Text] The research group of Researcher Takashi Iijima of the Environmental Material Research Laboratory, of the Government Industrial Research Institute, Tohoku, of the Agency of Industrial Science and Technology, and the Department of Engineering, Tohoku Gakuin University, have begun a full-scale project in an attempt to develop ferro-electric thin films that could become material used in the production of micro-actuator devices and the next-generation semiconductor memories. The group had been successful in producing a fourfold improvement in the dielectric property of a ceramic material by adding a 0.1-micron-thick niobium film on a ceramic (lead titanate)

material. The group needs to define the optimal conditions for the thin film preparation, as well as the quantity of the additive element that will maximize the dielectric constant of the ceramic material, before making the film commercially viable.

Ferro-electric materials are unique in that they are non-volatile—i.e., information is not lost with the power source off—and are highly capable of collecting and storing electricity. Thus, they are in the limelight as the next-generation key device that could result in a dramatically large capacity for DRAM condensers.

Previously, lanthanum and zirconic acid have been used as the third element for improving the dielectric constant. However, Researcher Iijima's group used niobium. Niobium was first added, in a nitrogen atmosphere, to the alkoxide (a compound between metal and alcohol) of lead titanate, and a coating solution was prepared by hydrolysis. The solution was spin-coated (at a rate of 2,000 rpm) over a quartz substrate to form a 0.15-micron-thick film. When that thin film was heated to 650-700°C, a perovskite single-layer film having an approximately 0.1-micron crystalline structure and stable electrical properties was obtained.

The group examined the electrical properties of the thin film and confirmed that its dielectric constant, the most important property for a dielectric material, was 350 at maximum, which was approximately four times that of lead titanate without the addition of niobium. The group also discovered that the dielectric constant would increase with the quantity of niobium. Researcher Iijima says this: "We want to find out the amount of niobium that maximizes the dielectric constant, and the optimal conditions for the formation of these thin films. We would also consider the possibility of conducting a joint research project with a corporation."

Initially, the group plans to examine the film's various properties—including electrolytic and piezoelectric properties—and develop applications with targets on infrared array sensor devices and micro-actuator devices, which can be developed even with a comparatively low dielectric constant.

Tokai Carbon To Use C/C Composites Technology for Large Components

94FE0776D Tokyo KAGAKU KOGYO NIPPO in Japanese 29 Jun 94 p 8

[FBIS Translated Text] Tokai Carbon Co., Ltd. (Tokai Carbon), has decided to begin building a new business based on the carbon-composite-formation and special-ceramic-coating technologies, both of which had been nurtured with the C/C composite business. Since its co-development with Mitsubishi Heavy Industries, Ltd. (MHI), of large C/C composite materials for the "orbital reentry experimental plane (OREX)," Tokai Carbon has been steadily expanding its space- development-related businesses. Therefore, Tokai Carbon decided to install a large calcination furnace and a coating device in the next year or two in order to deal with the need to develop large C/C composite materials. In addition, the company plans to aggressively develop heat and oxidation-resistant materials to cater to the general industrial sector based on the technologies that would be gained with the large composite development. In particular, the company intends to emphasize business development involving large composite materials that have been considered to be difficult to manufacture.

Tokai Carbon, in cooperation with MHI, had been developing C/C composite materials for space uses, and in February 1994, the Tokai Carbon-made OREX nose cone was mounted on the H-II test rocket that was successfully launched by the National Space Development Agency. That particular nose cone was fabricated by Tokai Carbon from MHI's CFRP after the carbon was made stronger and denser and after various coatings were applied, including that of silicon carbide and a special ceramic material.

Tokai Carbon has already established a production system including calcination, graphitization, and coating processes, at its Tanoura Plant (Ashikita Gun, Kumamoto Prefecture). For the time being, products are manufactured there strictly as requested by MHI.

Recently, the demand for large C/C composite materials has so rapidly increased that Tokai Carbon has begun to consider a specific plan to install a new, large calcination furnace and coating equipment.

Tokai Carbon, with its new business plan, intends to apply the series of technologies acquired during the development of aerospace heat-resistant structural and high-temperature heat-resistant materials to wide-ranging fields by installing the large calcination furnace.

At the same time, Tokai Carbon's Fuji Research Institute, in charge of basic research, was also successful in developing a material that could withstand a temperature of 1,700°C and demonstrated a strength of 2,000 kg/cm^2, which was more than fivefold better than the previously strongest material. Tokai Carbon hopes to be able to build its new business by targeting new markets with high-temperature, high-strength, and high oxidation-resistant materials, in addition to C/C composites, through the fusion of technologies, to include the technologies developed at the research institute.

MITI's AIST Proposes at SMIST Multi-National Research Program for Composites, Casting Technology

94FE0701A Tokyo KAGAKU KOGYO NIPPO in Japanese 16 May 94 p 1

[FBIS Translated Text] At the Special Meeting of Industrial Science and Technology (SMIST) of the Asia Pacific Economic Cooperation Ministerial Conference, to be held on 25 and 26 May 1994, in the People's Republic of China (PRC), the Agency of Industrial Science and

Technology (AIST), MITI, will propose two multinational cooperative research programs involving two-nation cooperative research projects currently under way with Singapore and Malaysia, respectively. SMIST was established for the purpose of drafting industrial technology action programs in the Asia-Pacific zone. AIST will invite other nations to participate in the above two programs.

The two topics to be proposed at the SMIST are AIST's specific key research cooperation projects, one of which is the high-performance metal-based composite-material development project in cooperation with Singapore, and the other is the sophisticated-casting-technology development project in cooperation with Malaysia. The high-performance metal-based composite-material development project, which was initiated in FY93, is being carried out in an attempt to develop composite materials from strong and rigid aluminum-lithium alloys that can be used in broad industrial fields. An extrusion-molder was installed for the project at the (Nanyo) Institute of Technology in Singapore, and the project is to continue through FY97. The Mechanical Engineering Laboratory, AIST, is the Japanese participant in the project.

The sophisticated-casting-technology development project was initiated in FY94 with a three-year plan in an attempt to develop strong cast products from tin, which is an abundant natural resource of Malaysia. Devices necessary for casting experiments, including analytical devices, will be installed at the Standard Industrial Technology Research Institute of Malaysia, and the Government Industrial Research Institute, Nagoya, of AIST will participate in this project as a cooperative member.

Although these two research projects are to be carried out between the two countries, AIST is hoping to upgrade research activities by having other nations participate in the projects. Therefore, the projects are to be pursued at the respective local sites, instead of sharing project assignments at both countries involved. In order to invite other nations' participation, AIST decided to propose the multi-national research projects at SMIST.

In September 1993, SMIST met for the first time in Japan, and the second meeting is to be held in Beijing in May 1994. The meeting will be co-chaired by the PRC and Japan.

Kyoto U. Produces Carbon Fibers by Pulse Injection Method

94FE0701B Tokyo KAGAKU KOGYO NIPPO in Japanese 16 May 94 p 14

[FBIS Translated Text] Professor Kenji Hashimoto's group at the Department of Engineering, Kyoto University, has successfully established an industrial production method for new carbon fibers. The new method starts with benzene as the carbon source, which is subjected to the pulse injection method to deposit carbon from the vapor phase to grow carbon fibers at a rate of four to five centimeters per minute. Although it had previously been known that carbon fibers could be formed by vapor deposition, the growth rate had been too slow to be considered for industrialization. In contrast, the new production method is highly promising for industrialization because it permits carbon fibers to grow at a rate that is faster than the previous method by several tens to several hundred times. Professor Hashimoto's group plans to continue the research in cooperation with a private corporation to move the method to an actual plant site where carbon fiber-reinforced plastics (CFRPs) are produced.

The new carbon fiber production method developed by Professor Hashimoto's group is essentially the method for vapor deposition of carbon by the pulse injection method using benzene as the carbon source and ferrocene, an iron-containing metal complex, as the catalyst source. More specifically, a benzene solution of ferrocene is pulse-injected through a nozzle at a rate of 0.02 ml per pulse into a reaction vessel maintained at a constant temperature between 1,000°C and 1,150°C, where mixed gas containing benzene and hydrogen, the latter as the carrier, is steadily flowing. As a result of the pulse injection, carbon fibers grow at a rate of 2,500 µm per second, or four to five centimeters per minute.

The process of carbon fiber formation is conjectured as follows. When the liquid pulse of the catalyst source makes contact with the hot wall of the reaction vessel, the liquid is instantaneously heated to a temperature above the thermal decomposition temperature, and the initial-stage clusters are densely formed. The clusters are then combined with each other to quickly form ultra-micro-particles of various sizes. When these particles make contact with benzene—i.e., the carbon source—the fibers will be formed at a high speed.

It has been confirmed that the carbon fibers produced by the vapor deposition method show essentially properties that are identical—such as heat resistance, strength, and electrical conductivity—to those of previous carbon fibers made by the calcination and carbonization of organic fibers, including acrylic fibers, and pitch-based fibers. It has also been confirmed that the new method permits the reliable formation of irregular-surface carbon fibers caused by the deposition of larger carbon particles, which tend to attach onto the surface of carbon fibers instead of aiding their growth. This irregular surface formation is said to advantageously improve the adhesion of carbon fibers to a matrix in CFRPs.

Professor Hashimoto's group has already filed an application for a patent concerning the pulse injection method for producing carbon fibers through vapor deposition. The group plans to find a cooperative private corporation to carry out a joint application research project to industrialize the process with a large reaction vessel, as well as to develop applications by taking

advantage of the method's high-speed growth of carbon fibers at a rate of four to five centimeters per minute of pulse injection.

Tohoku U. Develops Micro Pattern SiC, SiO_2 Thin Films

94FE0701C Tokyo NIKKAN KOGYO SHIMBUN in Japanese 17 May 94 p 6

[FBIS Translated Text] Director Minoru Matsuda and Assistant Professor Akira Watanabe at the Reaction Chemistry Research Institute, Tohoku University, have successfully developed, for the first time in the world, a new method for a functional inorganic thin film of silicon carbide and silicon dioxide showing a micro-pattern with approximately one-micron-wide lines. The method involves the ultraviolet-irradiation and heating of an organic poly-silane thin film. This new method is advantageous because it does not require a developing process using a highly toxic, organic solvent or an expensive dry-etching device. Thin films made by the new method are superbly heat resistant. The method is expected to significantly contribute to the production of large semiconductor patterns and to the drastic simplification of micro-fine fabrication of optical guidance paths. The group is scheduled to present a paper on this achievement at the 43d annual meeting of the Society of Polymer Science, Japan, to be held at the Aichi Prefecture Industrial Import and Export Hall in Nagoya City for three days beginning 25 May 1994.

Organic poly-silane, used as the starting material by the Tohoku University group, has a network structure of the polymeric silicon chain with an organic compound attached as its side chains. This polymer has recently been in the limelight as a potential semiconductor-related material because of its solubility in organic solvents while maintaining properties similar to that of crystalline silicon.

Director Matsuda's group treated this poly-silane, which had a network highly capable of undergoing photolysis, with ultraviolet irradiation and heating and produced an inorganic functional thin film with a micro-pattern of approximately one-micron-wide lines of silicon dioxide on a substrate of silicon carbide.

Specifically, a poly-silane thin film was first prepared on a substrate. When this film was exposed to ultraviolet light in air, molecules in irradiated parts were excited to sever poly-silane's bonds where oxygen would enter to cause oxidation. Subsequently, the film was placed in a vacuum and heated to a temperature of 300-1,000°C. The heating process converted the ultraviolet-unexposed parts of the poly-silane film into silicon carbide, and the ultraviolet-irradiated and oxidized parts into silicon dioxide.

Requiring neither an organic solvent, which is highly ignitable and toxic, nor an expensive device, the newly developed method was able to form micro-fine patterns in a safer and more efficient manner. Furthermore, although the resist thin film had to be removed in the previous method, it is possible to use both the resist film and the substrate together if poly-silane is used as the resist thin film for the purpose of adding functions to the resist film.

It is also possible to produce amorphous silicon with this new method by having an aliphatic group on the side chains of the poly-silane network. Thus, the method is likely to spur application method development for the formation of large semiconductor patterns and for the simplification of semiconductor micro-fine fabrication processes to produce optical guidance paths.

MITI To Form Two Committees for Development of Fibers/Polymer Technologies

94FE0701D Tokyo KAGAKU KOGYO NIPPO in Japanese 18 May 94 p 3

[FBIS Translated Text] MITI will organize two committees to examine the directions and topics for the next-generation fiber/polymer technology development. A committee made up of representatives from the participation of the Society of Fiber Science and Technology (SFST), the Japan Chemical Fibers Association (JCFA), and the Agency of Industrial Science and Technology (AIST) will examine how key technology development common to the next-generation textile industry should be carried out and will initiate R&D projects concerning potentially implementable topics under the "industrial science and technology" R&D system. Another committee will be formed mainly by younger academic researchers for forecasting the future of fiber (textile)/polymer based on their original, science-oriented ideas. The two committees are expected to compile respective reports by the spring of 1995.

The textile industry has had a long history as one of the leading industries in Japan. Technically, the industry was the key factor for polymer chemistry, as the synthetic textile industry grew. Although recent progress included the development of new synthetic fibers, such as aramid and polyester fibers, the tempo of the technical revolution has slowed considerably from the rapid rate of the 1960s.

The recent chemical technology has advanced at a fantastic rate to permit control manipulation at the atomic and molecular levels, as well as to benefit from R&D support technologies such as that of the computer. MITI plans to examine future technical development concerning fibers/polymers in an attempt to discover new breakthroughs.

The second committee primarily, made up of younger researchers—including assistant professors—will discuss the directions to be taken by fiber (textile) and polymer sciences. As soon as budgets are secured, MITI is expected to establish the committee with Technical Advisor Tatsuya Hongu, Toho Rayon Co., Ltd., as the

chairperson, within the office of the Textile Industry Restructuring Project Association. The committee will try to elucidate approaches for polymer science from the atomic and molecular angles.

On the other hand, the first committee, whose project is expected to be supported by MITI as its project, will be a mixed group of industrial, academic, and governmental representatives. The majority of its members will come from the "next-generation textile industry common key technology problem examination committee" of SFST, with other members coming from the "chemical synthetic fiber technical development roundtable group" of JCFA and from the National Institute of Materials and Chemical Research, AIST. The committee's chairperson will unofficially be Professor Seizo Miyata, Tokyo University of Agriculture and Engineering. The committee will have its first meeting as early as May 1994. The major objectives of this committee will be (1) the selection of development project topics for potentially implementable advanced fiber technology and (2) the best R&D system to pursue the topics.

NTT Develops High Thermal Resistance Polymer Material

94FE0701E Tokyo NIKKEI SANGYO SHIMBUN in Japanese 18 May 94 p 5

[FBIS Translated Text] NTT Corp. (NTT) developed a polymer with excellent heat resistance. The material, poly-siloxane deuteride, is stable up to approximately 400°C without any deformation or degradation because of its structure resembling that of glass with the formation of a chain consisting of silicon and oxygen. NTT hopes to apply this material primarily for optical, integrated circuits (ICs) that will be the key to the realization of optical communications and take advantage of the material's superb performance, which exceeds that of poly-methyl methacrylate (PMMA), the current optical-fiber material.

The new material is a polymer consisting of silicon, oxygen, carbon and deuterium. The backbone of the structure is the chain of alternately bonded silicon and oxygen, carbon is attached to the silicon, and deuterium is in turn bonded to the carbon. The NTT group used deuterium instead of hydrogen to supposedly increase the transparency of the polymer.

Moreover, the polymer made with hydrogen is not suitable to make optical devices because serious losses are encountered in optical communications at frequency bands of 1.3 and 1.55 micron. When hydrogen is replaced with deuterium, the bands with large losses shift toward the longer wavelength. NTT took advantage of this property.

NTT confirmed that the transparency of this polymer did not deteriorate after standing 10 hours in a 120°C environment. The new material has a low hygroscopicity of 0.1-0.2 percent, compared with one to two percent for PMMA. Therefore, it is unlikely that the performance of optical devices made of this new material will deteriorate because of changes in the refractive index.

In heat-resistance tests, the new material, like polyimide, which is known to be an excellent heat-resistant material, did not melt at temperatures of up to 400°C. When the temperature reached 600°C, the new material maintained approximately 90 percent of its original weight, compared with polyimide whose weight would drop to approximately 40 percent.

Using the new material, NTT test-produced an optical guidance path that would function as a passage for light in an optical IC. The path was made into a rectangular parallelopiped with an 8-micron-square cross-sectional area. NTT confirmed that the path was applicable for optical ICs based on the path's optical transparency of 98 percent per centimeter.

Confident that the material presents no problem in implementation, NTT plans to make efforts to improve the optical transparency through more precise fabrication of the optical guidance path. When that is done, NTT plans to replace the glass in current optical guidance paths with the new material.

Kobe Steel Develops Coating Technology for High Wear Resistant Al, Ti

94FE0701F Tokyo NIKKEI SANGYO SHIMBUN in Japanese 19 May 94 p 11

[FBIS Translated Text] Kobe Steel, Ltd. (Kobe Steel), has developed a coating technology for improving the wear resistance of titanium and aluminum. Applying the hard-plating technology, Kobe Steel was able to improve the adhesion, strength, and shock resistance of coated films. Wear resistance of titanium and aluminum was improved to almost the same level as that of iron-based materials. Poor wear resistance has always been a shortcoming of titanium and aluminum, which have the advantages of being lightweight and noncorrosive. The new coating technology is expected to be used in the production of auto components.

Kobe Steel's new coating is called "(Keni) coat." The technology is based on the hard-plating technology, which, despite being a low-temperature process, permits the control of film thickness. Kobe Steel added its own know-how to the hard-plating technology to be able to make the coating layer more stable.

As a result, titanium and aluminum coated by this technology were found to be able to withstand wear under a high surface pressure of up to several 100 kg/mm^2, which had never before been achieved with such existing methods as nitration, oxidation and melt-spraying.

A titanium-aluminum-vanadium alloy was coated with "(Keni) coat" and tested for durability with a rotating load. The durability of the coated alloy was found to be

approximately 10 times better than that of an alloy coated with any existing method, and nearly 15 times better than that of an alloy without any coating. This (Keni)-coated alloy also showed lubricity that was twice that of an aluminum alloy with a standard coating and was almost equal to that of untreated iron. The Vickers hardness was 600-800. The (Keni) coat film can be made as thick as 500 microns.

In this coating process, there is no possibility of deformation of titanium or aluminum because there is no heating. The coating adds a slightly golden color to the metal.

(Keni)-coated titanium and aluminum have already been tested in connecting rods and clutch components, respectively. Kobe Steel is hoping to be able to expand the applications of (Keni)-coated metals for automobile and airplane components, peripheral devices in the electronic industry, machines, and leisure goods whose use involves a great deal of friction by replacing the iron-based materials that have been used exclusively for these parts because of their wear resistance.

Latest Trend of Ultra High Temperature Materials

94FE0749 Tokyo NIKKEI MATERIALS & TECHNOLOGY in Japanese May 94 pp 102-112

[Article by Ryohei Tanaka, Technical Advisor, Ultra High Temperature Material Research Center]

[FBIS Translated Text]

1. Materials and Heat

The low temperature limit is zero degrees in the absolute scale, or 0K, which is -273.15°C. No matter how low a temperature is, it cannot be below this temperature theoretically or in reality. However, there is no limit to high temperatures. The plasma temperature in a nuclear fusion reactor, which has been considered to be a promising, ideal energy source, is said to be 100,000,000°C, and plasmas generated from various gases and used for melt-spraying of ceramics are said to be generally at a temperature in the vicinity of 15,000°C. The highest combustion temperature in a jet engine is estimated to be around 2,000°C. Nevertheless, the melting point of nickel, the primary component of a typical superalloy used in jet engines is only 1,455°C. The metal with the highest melting point is tungsten, which melts at 3,380°C. Generally speaking, ceramics melt at higher temperatures, and many of them have excellent heat resistance. Carbon can remain in a solid state until it sublimes at 3,700°C, silicon carbide decomposes at 2,400°C, and silicon nitride sublimes in the vicinity of 1,900°C. However, it is not always true that these materials are durable as long as they remain solid. Any material softens with increasing temperature and becomes readily deformed by a small external force.

It is necessary that machines and devices that are operated at a high temperature, e.g., jet engines and various electric power-generation devices, can be used reliably for a long period of time from several years to more than 10 years. Most of these machines and devices are made of metal. Under the conditions of a long-term operation, pure metal's use temperature limit will be approximately one-third its melting point expressed in the absolute scale. For example, nickel and cobalt can be used at temperatures of up to 300°C. Therefore, no pure metal has been implemented. Rather, metals are implemented in the form of an alloy that is reinforced by the addition of other elements.

2. What Are Jet Engines And Gas Turbines For Power Generation Made Of?

Of all the components of a jet engine, the turbine's rotor is subjected to the harshest conditions. Nickel-based superalloys have been developed and implemented specifically for the rotor. Although the melting points of these alloys are approximately 100°C below that of pure nickel, the alloys can withstand temperatures of up to about 950°C. However, the operating temperature for a jet engine (the turbine's inlet temperature, or TIT, which is several hundred degrees lower than the combustion temperature of fuel) has steadily increased each year, as shown in Figure 1, following the trend for larger and faster airplanes and less fuel consumption. The TIT for civilian passenger planes has already reached 1,400°C, at which even the superalloys would melt. Therefore, compressed air is used to cool the rotor from inside in order to prevent the rotor material from melting.

Needless to say, remarkable progress has been made in material development, and stronger superalloys that have a higher temperature resistance have been developed one after another. Also, the precision casting method was improved to form single crystals rather than prism-shape crystals by directional solidification. In particular, rotors and stators can now be made by precision casting. It may now be safely stated that today's jet engines have made such significant progress, including the adoption of the forced cooling system, that jumbo planes are flying with them.

It must be noted, however, that the maintenance of the material's strength by cooling is not sufficient.

With the exception of certain noble metals, such as gold and platinum, most metals undergo oxidation and corrosion in an atmosphere of high-temperature air or combustion gas. These reactions tend to proceed faster as the temperature increases. The nickel-based superalloys contain approximately 10 percent chrome and several percent aluminum for reinforcement, whereas many cobalt-based superalloys contain more than 20 percent chrome. Despite the development of these alloys, it is still impossible to completely prevent the alloys from corroding in a combustion gas environment when the jet engine's operating temperature is steadily increasing.

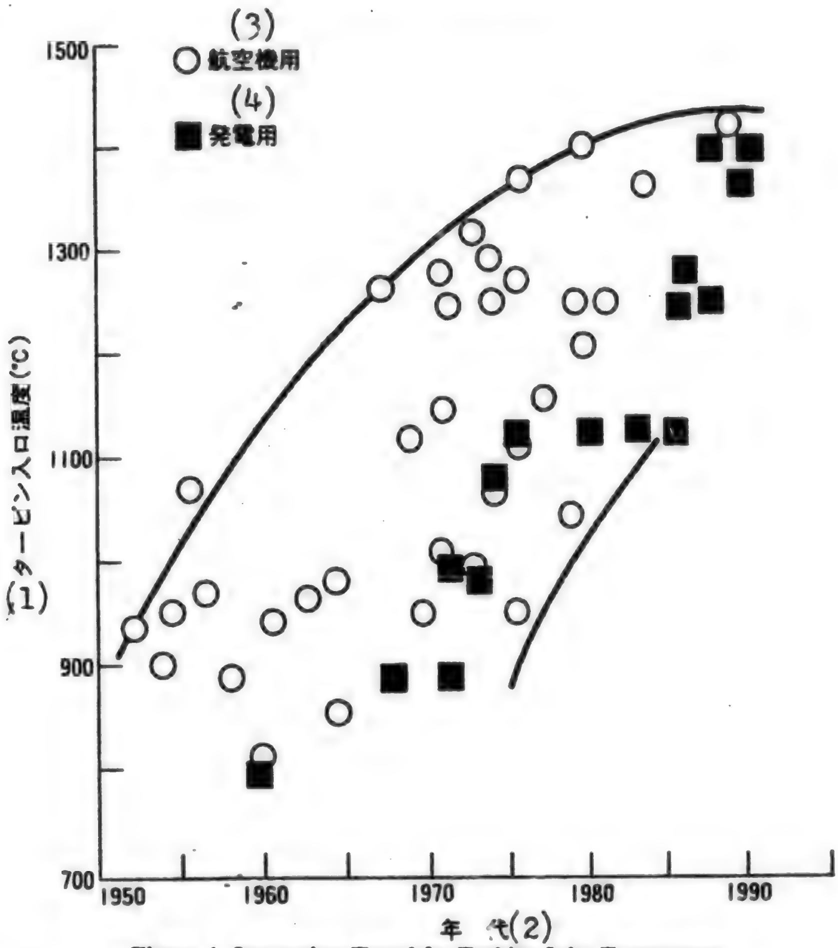


Figure 1. Increasing Trend for Turbine Inlet Temperature

Key: (1) Turbine inlet temperature (°C); (2) Year; (3) Aircraft turbines; (4) Power generators

Thus, the new technology has been adopted to modify the surface of a rotor or a stator by using plasma to melt-spray at a high speed and laminate a zirconia-based ceramic material over the surface. This technology, called the heat-barrier coating technology, is based on zirconia's thermal barrier effect—because zirconia's thermal conductivity is lower than that of the superalloys—in order to prevent the metal components prevent heating to a high temperature, as well as on zirconia's excellent corrosion resistance.

Also shown in Figure 1 is the trend associated with TITs for power- generation gas turbines. The TITs appear to follow, after some time lag, a trend similar to that of TITs for jet engines, because the jet engine technology is applied on the ground to the power-generation technology. Many gas turbines for power generation are larger than those used for jet engines. In addition, power-geration turbines use cheaper fuel that generates more impurities (ash), which cause harsher corrosive conditions for turbine components. At the same time, the recent problems concerning the global environment have necessitated the reduction of fossil fuel consumption and the minimization of carbon dioxide emissions into the environment. In Japan, the co-generation system that uses a combined cycle of gas and steam turbines has recently become popular among thermal power plants, which supply 65 percent of the nation's total power-generation capacity. Although the thermal efficiency of a gas turbine alone is far below 40 percent at a TIT of 1,300°C, its HHV (higher heating value) thermal efficiency in a co-generation system can be as high as 47 percent at the same TIT. Generally, the thermal efficiency of these thermal engines increases with the TIT. However, the nickel- or cobalt-based superalloy used to fabricate turbine components at this TIT can tolerate temperatures of up to only 950°C, as mentioned before.

Thus, it is imperative to improve the cooling structure and increase the volume of cooling air to cope with higher TITs. Thus, the current air-cooling technique can no longer increase the thermal efficiency at a TIT higher than 1,600°C.

Gas turbines without any cooling system will probably be developed if a new ultra-high-temperature material is developed with heat resistance better than that of the superalloys, which appear to have reached their limits. According to the computations, it is said to be possible to achieve 51-percent thermal efficiency for a no-cooling co-generation system with a TIT of 1,300°C and to increase the efficiency to 58 percent if the TIT is raised to 1,700°C without cooling. This calculated thermal efficiency is 11 percent greater than the previously mentioned thermal efficiency of 47 percent for the co-generation system at a TIT of 1,300°C.

If that is achieved, simple computation tells us, both fossil fuel consumption and carbon dioxide emissions can be reduced by slightly more than 23 percent, which will be a significant contribution to the preservation of the global environment, as well as to the conservation of energy.

3. Impact on Space Planes

A plan is under way to develop a hypersonic transport plane that can fly from Tokyo to New York in three hours instead of the 10 hours the current transport planes require. Such a hypersonic plane needs a speed of Mach 5, or 6,000 km/h. A space shuttle is engulfed in flames upon its re-entry into the atmosphere because of aerodynamic heating caused by the collision with air at a high speed. Many readers will remember the topic of heat prevention with ceramic tiles. In February 1994, Japan launched the re-entry experimental plane, OREX, using the domestically-developed H-II rocket. The unmanned space shuttle HOPE is scheduled to be launched in the year 2000 by the same rocket. After that, we will soon be into the era of manned space shuttles and space planes—including the above-mentioned hypersonic planes—that can take off and land horizontally.

Rockets use an engine that burns hydrogen, and current jet airplanes use a turbo-jet engine for propulsion. Space planes are said to require a new propulsion system called the "scram jet engine," which is under development. That engine's operating temperature easily exceeds 2,000°C, and the nose cone at the front end of the plane's fuselage is said to reach a temperature of 1,800°C, with the leading edges of the main wings said to be heated to 1,450°C. No superalloy can be used for these components because they cannot withstand such temperatures. As mentioned before, ceramics are used for thermal barrier coating. If superalloys cannot be used, can we use ceramics to construct rotors and stators?

As will be discussed later, there are many problems to be overcome with ceramics, which occupy one corner of the field of ultra-high-temperature materials. The application of ceramics in rotors and stators for jet engines, as well as for power generation, is still at the R&D stage. For all the reasons discussed above, we need to develop ultra-high-temperature materials, or structural materials that are lightweight, corrosion resistant, and sufficiently strong at ultra-high temperatures above 1,000°C.

4. Ultra-High-Temperature Materials Expected to Have Heat Resistance Better Than That of Superalloys

Let us discuss ultra-high-temperature materials that are expected to have heat resistance better than that of superalloys.

4.1 Intermetallic compounds

An intermetallic compound (often abbreviated to IMC) is a compound made of metallic elements. Generally speaking, IMCs are hard and brittle. Although they are implemented in various ways in the field of functional materials, e.g., rare earth metal magnets and hydrogen-occlusion alloys, IMCs are being considered, depending on future development, for potential structural materials only in the field of ultra-high-temperature materials. Today, compounds of aluminum (aluminides) with titanium, nickel and molybdenum are in the limelight. Particularly, the compound with titanium (TiAl) is being most actively studied, e.g., one of the next-generation projects jointly carried out by the Agency of Industrial Science and Technology (AIST) and NEDO (New Energy Development Organization). The compound has a density of approximately 3.8, less than one-half that of a superalloy, and has a greater specific strength than that of the superalloys. However, it is likely that its maximum tolerable use-temperature will not exceed 1,000°C.

The research team of AIST/NEDO's next-generation project is also studying niobium aluminide (Nb_3Al). Although the melting point of this IMC is as high as 1,960°C, when niobium is oxidized to form Nb_2O_5, the melting point falls to approximately 1,550°C. Thus, the IMC needs to be improved on its oxidation stability and brittleness. Another IMC of molybdenum and silicon ($MoSi_2$) melts at 2,250°C, withstands oxidation well, and is malleable at high temperatures. However, its brittleness and machinability at room temperature need to be improved.

The nickel-aluminum intermetallic compound NI_3Al has been studied extensively because it played an important role in upgrading the high-temperature strength of nickel-based superalloys. However, it does not look promising, because of a melting point below 1,500°C. On the other hand, some time during 1994, General Electric Corporation is reportedly planning to apply NiAl with a melting point of 1,638°C to jet engines. That development is worthy of attention.

4.2 High-melting alloys

Alloys made from tungsten (W; melting point, 3,380°C), molybdenum (Mo; melting point, 2,615°C), niobium (Nb; melting point, 2,468°C), and tantalum (Ta; melting point, 2,998°C) are called high-melting alloys; in particular, alloys with a high-temperature strength greater than

that of the superalloys have been developed from tungsten and molybdenum. The worst shortcoming of these high-melting alloys is oxidation resistance. In addition, their higher densities are also disadvantageous for fabricating rotating components not only for the aerospace field but also for devices on the ground. Another problem with these alloys is brittleness at room temperature. Nevertheless, the TZM alloy, made by adding small amounts of titanium and zirconium to molybdenum, is used for high-grade molds.

4.3 Ceramics

Recently, attention has been focused on silicon nitride (Si_3N_4) and silicon carbide (SiC), both of which belong to the group of non-oxide-based ceramics. Both have been chosen by the ceramic gas-turbine project of AIST/NEDO in an attempt to apply ceramics for the rotors and stators of a small gas turbine that cannot be air-cooled. In particular, the raw material preparation and production methods for silicon nitride have been improved so substantially that its bending strength at 1,200°C has been more than doubled in roughly the last 10 years. How large a component silicon nitride can be fabricated into will be determined by the future improvement on the material's strength as well as reliability.

4.4 Composite materials

Here, the focus is on metal-based materials (MMCs or FRMs) and ceramic-based materials (CMCs or FRCs). However, the most promising are C/C composite materials in which a carbon matrix is reinforced with carbon fibers.

The most studied MMCs include titanium- and aluminum-based materials reinforced with silicon carbide fibers. Some attempts have been made to use these materials to reduce the weight of an auto engine, although they are not exactly ultra-high-temperature materials, because of their inadequate heat resistance. A study of MMCs with an IMC matrix has not yet been started on a full scale. CMCs of interest are based on the matrix of silicon carbide, which is reinforced with carbon or silicon carbide fibers. As shown in Figure 2, CMCs are showing specific strengths greater than those of superalloys at temperatures near or above 1,000°C. Although details have not been disclosed, Rolls Royce Motor Company Ltd. (Rolls Royce) of U.K. is reportedly trying to incorporate a CMC into components of a gas turbine before the end of 1994, based on the claim that silicon nitride can be used at temperatures of up to only 1,200°C. According to the company's prediction of 1987, when approximately 50 percent of the total weight of a jet engine was due to superalloys, the percentage would drop to approximately 33.33 percent by the year 2010. At the same time, the percentage of each of MMC and CMC would increase to 30+ percent. After a sweeping revision of the 1987 prediction, however, R.J. Parker of Rolls Royce announced that the percentage of each of MMC and CMC in the year 2010 would be at a level of only several percent.

The C/C curve in Figure 2 appears to be most noteworthy. The C/C materials are made with the matrix of carbon or carbonized resin, reinforced with high-strength, high-elasticity carbon fibers. Their densities range from 1.8 to 1.9, which are less than one-fourth that of superalloys; yet their specific strengths are the highest among heat-resistant materials at temperatures above 1,000°C. Moreover, it is remarkable that the C/C materials can maintain their strengths at temperature above 2,000°C. Some C/C materials have already been fabricated into the brake material for the Concorde, the supersonic passenger plane, and the nose cones and the main wing's leading edge for space shuttles. However, oxidation is a serious problem for these composite materials, for which many research projects—including projects involving the development of the ceramic coating method to improve oxidation resistance—will have to be initiated.

5. Ultra-High-Temperature Materials Research Center

Ultra-high-temperature material research began only recently. There were many existing research devices that needed to be upgraded to deal with higher temperatures and pressure for the study of ultra-high-temperature materials. It was costly to install new equipment, and such capital investment was not always efficient. Therefore, plans called for the national government to assist in concentrating facilities for ultra-high-temperature material research in one place, where researchers who would need to use such facilities could do so on a lease basis. Thus, the Ultra-High-Temperature Material Research Center was established in March 1990. The Center was equipped with many research devices that could easily be considered the world's most advanced. Simultaneously, the Ultra-High-Temperature Material Research Institute was also set up by the private sector for the purpose of carrying out independent, cooperative, and consigned research projects and test evaluations that utilized the Center's facilities. It is expected that the Center and the Institute together will make significant contributions not only to R&D involving ultra-high-temperature materials, but also to many industrial fields through active use of the Center's facilities.

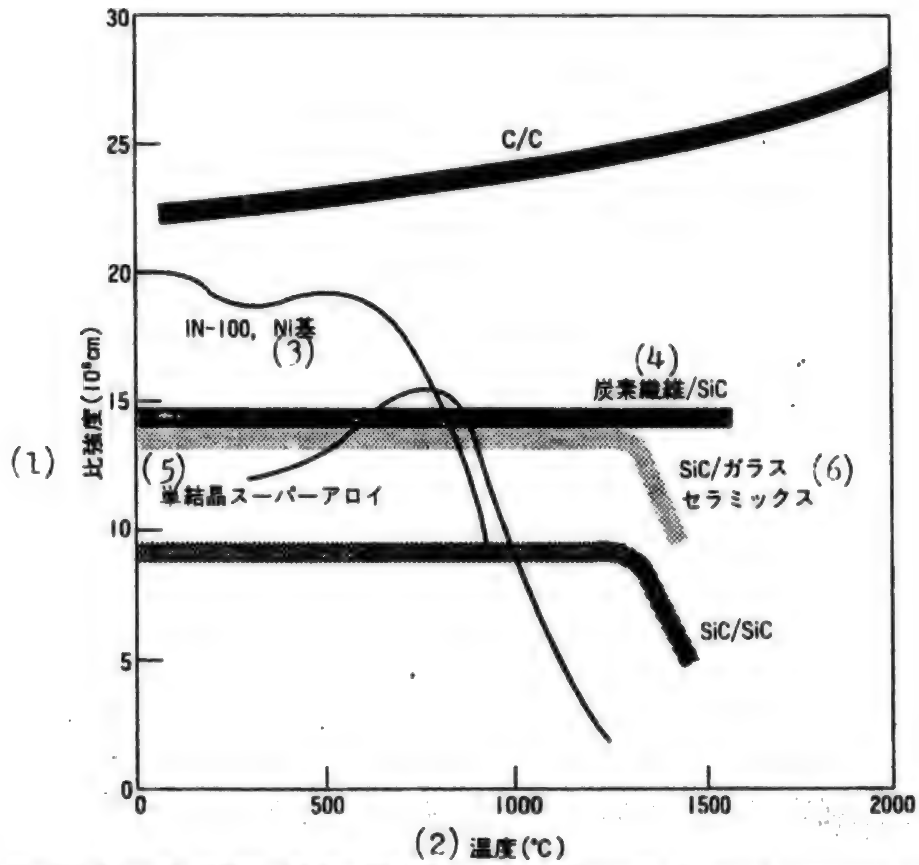


Figure 2. Specific Strength of Typical Ultra-High-Temperature Composite Materials (composite materials are all two-dimensional fabrics)

Key: (1) Specific strength (10^5 cm); (2) Temperature (°C); (3) IN-100, Ni-based; (4) Carbon fiber/SiC; (5) Single-crystal superalloy; (6) SiC/glass ceramics

Advanced Technologies for High Temperature Gas Turbines

94FE0747 Tokyo TOSHIBA REBYU in Japanese Apr 94 pp 257-260

[Article by Tomohiro Honma, Matuo Miyazaki, and Atsuhiko Izumi, Toshiba Corp.]

[FBIS Translated Text]

1. Introduction

Since the mid-1980s, an increasing number of combined-cycle power-generation plants built around the nucleus of gas turbines have been aggressively constructed for the purpose of improving the performance of power facilities and diversifying their operation. Many of those plants in Japan and elsewhere in the world have been compiling superb performance records based on their advantages. At the same time, from the standpoint of energy conservation and environmental protection on a global scale, further improvement in performance and environmental preservation function has been demanded of gas turbines. In response, an advanced combined-cycle plant using a gas turbine with its inlet temperature of 1,300°C has been placed into operation. However, the gas turbine's higher performance through the turbine's higher temperature tolerance and its better capability of preserving the environment appears to be in demand constantly.

Thus far, Toshiba Corp. [Toshiba], in an attempt to raise the inlet temperature and improve the performance of gas turbines, has successfully achieved the technical demonstration of a 1,100°C-class gas turbine and the overall demonstration of a 1,300°C-class gas turbine. With that development, Toshiba has been able to establish the method of evaluating the remaining life of the high-temperature components of a gas turbine. From an early stage in the project, emphasis was placed on the development of the combustor, one of the key components of a gas turbine, which would also become the focal point of environmental preservation. In particular, a dry, low-NO_x combustor, which was developed by

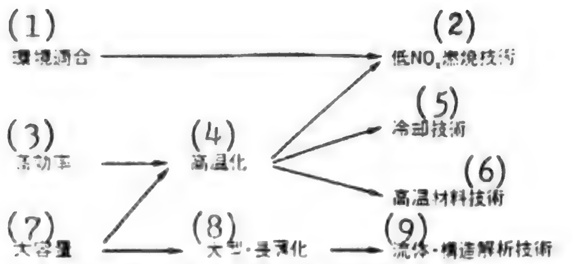


Figure 1. Technical targets and tasks for advanced high-temperature gas turbine. Plan to solve technical problems to satisfy future needs.

Key: (1) Environmental compatibility; (2) Low NO_x combustion technology; (3) High efficiency; (4) Temperature increase; (5) Cooling technology; (6) High-temperature material technology; (7) Capacity increase; (8) Size and blade length increase; (9) Fluid, structural analysis technology

Toshiba with a simple structure, was mounted on a large gas turbine that began operation in March 1993 at Oi Thermal Power Plant of Tokyo Electric Power Co., Ltd., and has been performing superbly. While those development activities are going on, it is our pleasure to discuss Toshiba's technical development of the next-generation high-temperature gas turbine with a turbine inlet temperature exceeding 1,300°C.

2. Targets for Development of Next-Generation Gas Turbine, and Technical Problems Involved

Although the gas turbine's inlet temperature has reached 1,300°C, it is expected that the temperature will be increased to 1,400°C in the next generation, not long after the year 2000. For the most part, this expectation is based on future progress in cooling technology and new material development, similar to the situation associated with airplane engines. Generally, targets and technical problems given in Figure 1 need to be dealt with for the development of a commercial power generator. A efficient low-NO_x combustion technology will be required for the combustor to control localized high-temperature combustion as much as possible, because at higher temperatures the NO_x emission increases exponentially. At the same time, it will be mandatory to reinforce the cooling for high-temperature components, particularly turbine buckets and nozzles, and to use components made of superbly heat-resistant materials.

Furthermore, it will be absolutely necessary to establish a coating technology for high-temperature components to make them more durable by improving their corrosion resistance and heat insulation capability. It is also necessary to increase the generator capacity, so that future power plants will not require much space. Also, the plants themselves may be constructed in a simple fashion and maintained better. To increase the capacity, design technology for longer blades will have to be developed.

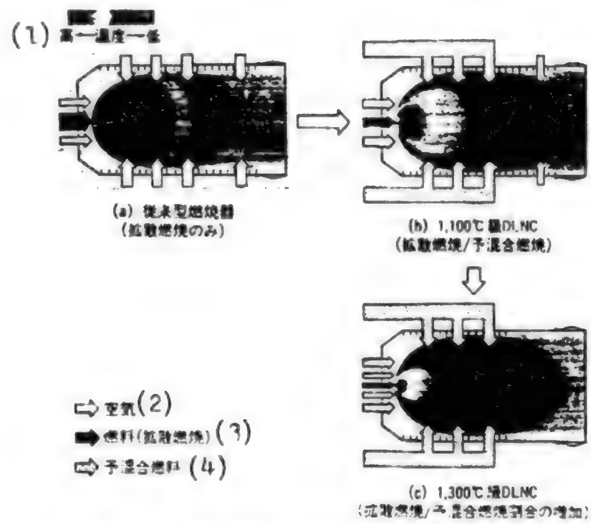


Figure 2. Combustion method of dry low-NO_x combustor. Local high-temperature combustion zone where NO_x is generated is diminished by increasing the ratio of premix combustion.

Key: (a) Existing combustor (involving only diffusion combustion); (b) 1,100°C-class DLNC (diffusion combustion/premix combustion); (c) 1,300°C-class DLNC (with a higher ratio of diffusion combustion/premix combustion); (1) High <—Temperature—> Low; (2) Air; (3) Fuel (diffusion combustion); (4) Premix combustion

3. Elemental Technology Development for the Next-Generation Gas Turbine

3.1 Low-NO_x combustion technology

In its gas-turbine development project, Toshiba gave priority to the development of an NO_x reduction technology from the standpoint of environmental preservation. It was difficult to reduce the NO_x emission from combustion in a gas turbine, which had always been operated under higher pressure with a higher load against environment, than in steam-power boiler combustion. Various attempts, including the addition of water or steam to the combustion flame, had been made to reduce the NO_x emissions of a gas turbine.

After screening many methods, Toshiba successfully optimized the diffusion/premix-dilution combustion method, illustrated in Figure 2, to develop a DLNC (dry low-NO_x combustor) that used neither water nor steam, both of which tended to decrease thermal efficiency. The combustor was constructed in a simple fashion, with no moving parts in high-temperature regions in the vicinity of the combustor. In order to secure highly reliable premix combustion in a wide operation range, the ratio of premix, the position of premix, and the limit for backfire were carefully examined and tested.

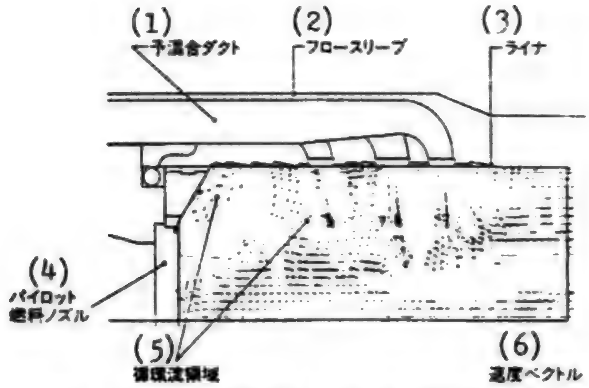


Figure 3. Three-dimensional flow-field analysis in combustion liner. The combustor needs to be designed to form a stable circulation region under all operating conditions.

Key: (1) Premix duct; (2) Flow sleeve; (3) Liner; (4) Pilot fuel nozzle; (5) Circulating flow region; (6) Speed vector

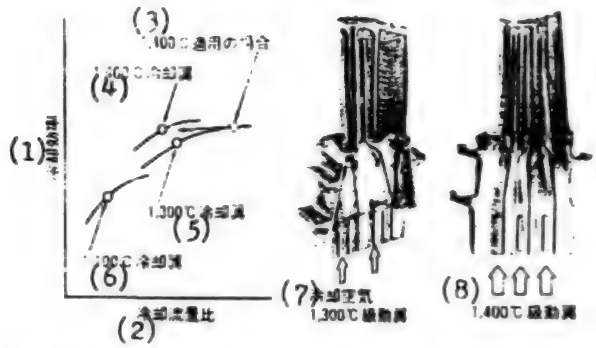


Figure 4. Air-cooled buckets for 1,400°C-class gas turbine. Significant improvement in cooling performance can be gained through improved cooling structure and precooling.

Key: (1) Cooling efficiency; (2) Cooling flow-rate ratio; (3) When used in 1,400°C-class turbine; (4) Cooling blade for 1,400°C-class turbine; (5) Cooling blade for 1,300°C-class turbine; (6) Cooling blade for 1,100°C-class turbine; (7) Cooling air for 1,300°C-class bucket; (8) 1,400°C-class bucket

As disc ssed earlier, the DLNC for 1,100°C-class gas turbines has been operating in a trouble-free fashion, with NO_x emissions reduced to approximately one-fifth that of the previous model. Currently, verification tests are being conducted for a DLNC to be implemented for 1,300°C-class gas turbines. That DLNC's target is NO_x reduction of one-tenth to one-twentieth, with an even higher premix-combustion ratio. At the same time, another DLNC is being developed to be implemented with 1,400°C-class gas turbines. For this development, experiments and analyses are being carried out in an attempt to increase the premix-combustion ratio and to improve the uniformity of the premix. Because NO_x emission reduction and combustion stabilization are contradictory to each other, it is important to secure stable combustion under the condition of a high premix ratio. Therefore, the development is being pursued with emphasis on reliability improvement through confirmation of flame conditions inside the combustor in combustion tests under various operating conditions, including load shutdown. In those tests, a circulation region for flame stabilization was maintained by using flow-field analysis inside the combustor, shown in Figure 3.

Incidentally, Toshiba has also initiated the development project for another DLNC, which burns low-calorie fuel, obtained by gasifying coal with abundant reserves, which is expected to become a fuel of the future after LNG.

3.2 Cooling technology development

The development of cooling technology is indispensable for increasing the t bine's inlet temperature. In the past, drastic improvements in the temperature were primarily supported by improvements in cooling technology. The structures and cooling performances of the cooling blade for the 1,300°C-class gas turbines and those for 1,400°C-class gas turbines are compared in Figure 4.

The heat-conducting performances of both the inner and outer surfaces of a cooling blade have been precisely estimated on the basis of model tests and numerical analyses; the rib shape inside the cooling flow passage has been optimized, and the number of passages was increased; high cooling performance has been confirmed for the 1,400°C-class cooling blade also on the basis fo wind tunnel tests. Furthermore, efforts are being made to optimize the conditions for a cooling medium, i.e., a method to improve the cooling effect by air by precooling it and a method to use steam with excellent heat conducting characteristics as a substitute for cooling air are being studied. In particular, the cooling system for the steam-cooled nozzle, shown in Figure 5, is promising in that it can exceed the limits of the air cooling system. In addition, Toshiba, including its own R&D Center, is in the process of building a data base through thorough evaluation of the prediction of heat transfer and the effect of film cooling by carrying out elemental tests and analyses.

3.3 High-temperature material development

The gas-turbine materials that are used for the major high-temperature components, such as buckets and nozzles, need improvements in two areas in addition to the cooling technology. They are the strength of base materials and the stability against environment, in particular, combustion-gas atmosphere and high temperature. As far as the high-temperature strength is concerned, the implementation of directionally solidified (DS) alloys—made from ordinary cast, heat-resistant alloys with crystal growth control—and single crystal (SC) alloys has been reported to be imminent. Some components, shown in Figure 6, have been test-produced and

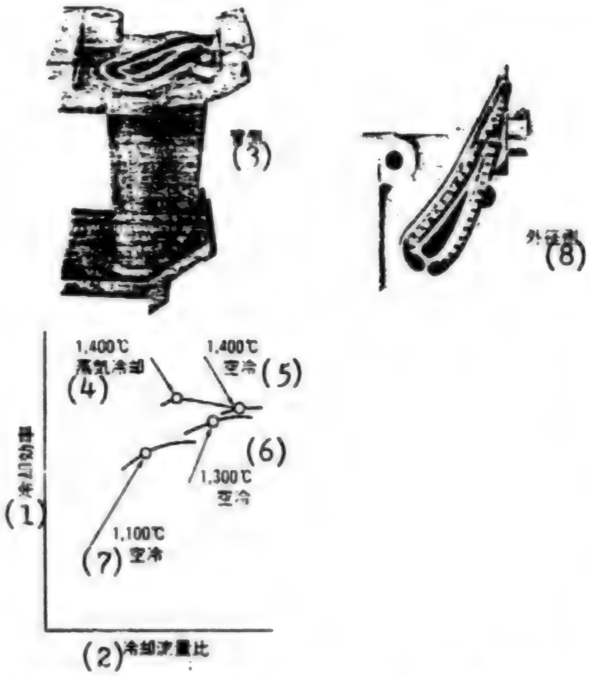


Figure 5. Performance and structure of steam-cooled nozzle. A promising high-performance cooling technique to replace air cooling.

Key: (1) Cooling efficiency; (2) Cooling flow-rate ratio; (3) Back side; (4) 1,400°C steam cooling; (5) 1,400°C air cooling; (6) 1,300°C air cooling; (7) 1,100°C air cooling; (8) Outer-diameter side

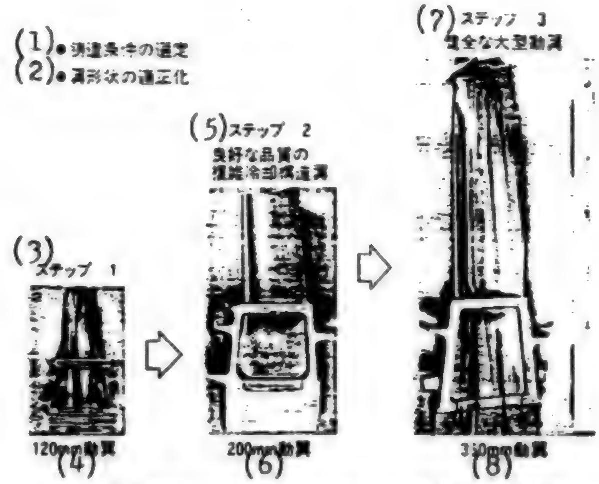


Figure 6. Trial casting and evaluation of DS and SC buckets. Bucket size is increased step-wise toward implementation.

Key: (1) Selection of casting conditions; (2) Optimization of bucket shape; (3) Step 1; (4) 120mm bucket; (5) Step 2: Bucket made of high-quality material with complex cooling structure; (6) 200mm bucket; (7) Step 3: Large, soundly built bucket; (8) 350mm bucket

mounted on test turbines at Toshiba. Also potentially viable are new materials of the future, such as oxide-dispersion- strengthened (ODS) alloys and ceramics. Those materials have also been made into gas-turbine high-temperature components for evaluation (Figure 7).

In order to improve the stability against environment, the materials are required to possess many functions, including corrosion and oxidation resistance and thermal insulating capability. Toshiba is in the process of developing a composite coating technology that is an advanced form of either the vacuum plasma spray-coating (VPS) technology or the ceramic thermal barrier coating (TBC) technology.

In trying some of these materials under development, emphasis is placed on the implementation of these materials through actual test-casting of high-temperature components from them, optimization of the casting process conditions, and performance of verification tests and evaluation with actual operation of a trial gas turbine, in addition to measurements of the basic properties of those materials.

3.4 Capacity increase technology development

The design technology for highly reliable, longer blades that can cope with the increased quantity of working

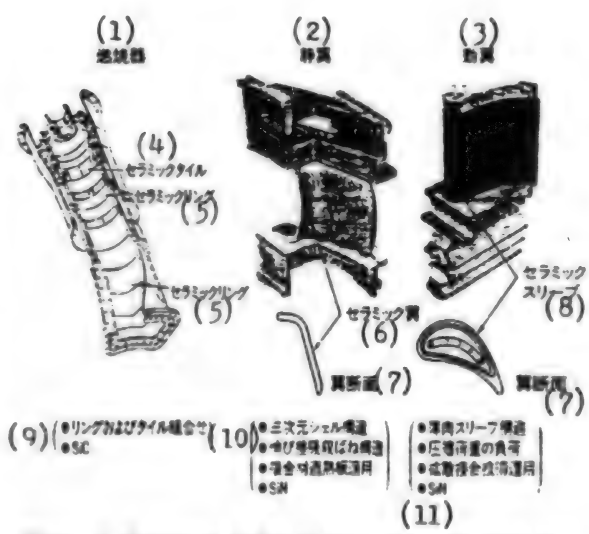


Figure 7. Optimum design of ceramic components for gas turbine. Optimal ceramic structures are designed for individual components.

Key: (1) Combustor; (2) Nozzle; (3) Bucket; (4) Ceramic tile; (5) Ceramic ring; (6) Ceramic blades; (7) Cross-section of blade; (8) Ceramic sleeve; (9) Combination of rings and tiles, SiC; (10) Three-dimensional shell structure, Differential expansion absorbing spring structure, Application of composite thermal barrier, SiN; (11) Thin-gauge sleeve structure, Application of compressive load, Application of diffusion bonding technology, SiN

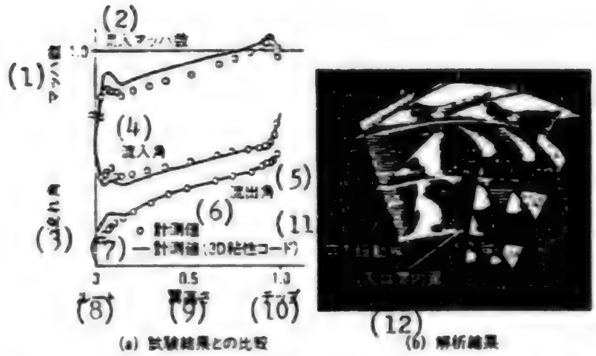


Figure 8. Application of CFD. The effectiveness of CFD was confirmed with its application to the transonic region of a compressor's rotor.

Key: (a) Comparison with test results; (b) Results of analysis; (1) Mach number; (2) Inflow Mach number; (3) Flow angle; (4) Inflow angle; (5) Outflow angle; (6) Measured values; (7) Measured values (3-D viscosity cord); (8) Root; (9) Blade height; (10) Tip; (11) First-stage rotor; (12) Inlet guide blade

fluid for a compressor or a turbine is the key to the development of a greater capacity for a unit turbine. Even for the 1,300°C-class gas turbine, the flow rate at the first-stage rotor tip of a compressor or the final-stage rotor tip of a turbine already exceeds the speed of sound. Thus, the design for fluid with high performance in the transonic region is indispensable for the next-generation gas turbine, which is expected to have a greater flow rate than the 1,300°C-class gas turbine. With the recent, fantastic progress in CFD (computational fluid dynamic) technology, the long-blade design has been blessed with much-improved analytical precision and computational speed. Shown in Figure 8 is a comparison of analytical and test results of a transonic compressor. The flow around the blade's tip section, which was previously difficult to predict, has been defined clearly according to the graph. One of the advantages of using CFD is to be able to examine a total flow field, which can be understood with difficulty by a test, from different angles.

A blade material also needs more strength with the increase in its length. A lightweight alloy, such as a titanium alloy with excellent specific strength, will be needed for a compressor's rotor blade. On the other hand, for the final-stage bucket of a high-temperature turbine, long blades made of a DS alloy with excellent strength at high temperatures will be needed. However, because of the crystalline isotropy, structural analysis technology for non-isotropic materials will be required to design long blades.

An example is given in Figure 9 to show differences between Young's modulus and the bucket's characteristic frequency for non-isotropic DS and SC alloys.

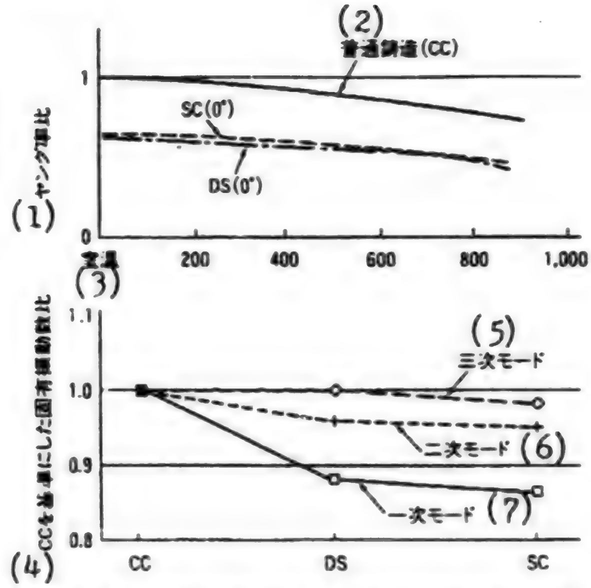


Figure 9. Structural analysis of non-isotropic materials. The technology is indispensable for the design of long blades.

Key: (1) Young's modulus ratio; (2) Ordinary cast alloy (CC); (3) Room temperature; (4) Ratio of characteristic frequencies based on CC; (5) Third-degree mode; (6) Second-degree mode; (7) First-degree mode

Young's moduli of DS and SC alloys in the blade length direction were only 60 to 70 percent of the Young's modulus at the normal temperature of an ordinary cast alloy. Using an orthogonally non-isotropic model based on the non-isotropic properties of these materials, a structural analysis cord was developed. Using this, the characteristic frequencies of the bucket were computed, and it was found that the frequency values for the lower-degree modes were lower. Therefore, a careful detuning design for the long blade becomes more crucial than ever.

4. Postscript

Based on previous technical development achievements and compiled data concerning actual turbines, Toshiba is pursuing the development of elemental technologies in a broad sense to face the era of the next-generation high-temperature gas turbine. The development program includes several concurrent projects including the development of low-NO_x combustion technology to be used for high-temperature turbines, the development of cooling technology and heat-resistant materials, and the development of advanced technologies concerning ceramics and measures to cope with various types of fuel. Finally, the authors would like to ask users not to hesitate to make suggestions concerning the possibility of implementation of any achievement by Toshiba at existing power plants.

Ceramic Engine Application Update

94FE0745A Tokyo NIKKEI MATERIALS & TECHNOLOGY in Japanese May 94 pp 46-47

[Article by Masaaki Maruyama based on his interview with Hideo Kawamura, of the Isuzu Ceramics Research Institute]

[FBIS Translated Text] A development-project leader for a major ceramics-maker speaks of his hope when he says that "he is the one who can really establish a market for structural ceramics." The "he" he speaks of is none other than Director Hideo Kawamura, of the Isuzu Ceramics Research Institute (ICRI) (Fujisawa City, Kanagawa Prefecture). For more than 10 years, Kawamura has devoted his efforts exclusively to the development of ceramic engines. He is an engineer who is leading what is probably the only development team still active in the world.

In the early 1980s, when raw-material powders and sintered materials made of structural materials such as silicon nitride, silicon carbide, and zirconia appeared on the scene, the development of the ceramic engine was initiated as one of the major applications for ceramics. "The attractiveness of the ceramic engine was its high energy efficiency without cooling, which was a result of the replacement of the metal components around the combustion chamber with ceramic components for a reciprocating engine to be mounted on automobiles." The primary target of the development was naturally the auto market, with a conspicuously high demand.

At the time, major corporations from Japan, Europe, and the United States, each with their own development team, were competing with one another. In the second half of the 1980s, however, all of the corporations, with the exception of Isuzu Motors Ltd. (Isuzu Motors), curtailed development activities dramatically, because of rising costs and technical uncertainty. The general consensus is that they all essentially halted development. "Isuzu Motors decided to invest in the development of the ceramic engine, which was regarded as a key, original technology, on the assumption that the corporation could not survive in the mature auto industry unless it had recourse to its own unique technology."

Target Co-Generation Use with Efficiency of More than 50 Percent

The disappearance of rivals did not lessen Kawamura's desire to develop and implement ceramic engines.

It wasn't until 1993 that the development team led by Kawamura joined the natural-gas-burning ceramic-engine development project. The project was called the "Development of a natural-gas-burning ceramic-engine system" and was initiated in FY93 on a five-year plan by the Japan Gas Association (JGA), with a subsidy from the Agency of Natural Resources and Energy, MITI. In addition to ICRI, which was in charge of developing the engine and its system, four gas companies—including Tokyo Gas Co., Ltd.; Noritake Co., Ltd., in charge of ceramics; and Nippon Shokubai Kagaku Kogyo Co., Ltd., in charge of the catalyst—were to be involved in the start of the project.

Kawamura confidently says, "We are participating in the project with nothing less than full confidence that we will be able to achieve successful implementation." Kawamura is confident that the basic form of a two-stroke engine was completed when it was published in 1992. Needless to say, further work is needed to reduce costs and improve performance and reliability to establish a mass-production system; also, a total system needs to be perfected. Kawamura explains this point in terms of "the balance between the costs and the value payback."

The gas engines to be developed in the above project are for co-generation (thermal-electrical power-generation) systems, with the core engine being of a medium scale with an output of 200 kW. According to Takeo Miyakawa, the head of the Ceramic Gas Engine Development Project Department, JGA, "Our targets are as follows: engine operation efficiency to be more than 50 percent; overall efficiency through the recovery of energy from high-temperature exhaust gas to be 86 percent; the heat-to-electricity ratio to be 0.9; the system's package cost to be ¥250,000/kW; and the overhaul period for major components to be more than 1,000 days." It is to be noted that the reason for the high heat-to-electricity ratio target of 0.9 came from the fact that heat can be recovered in the form of high-temperature steam.

Kawamura views the potential market this way "The project is viable in its targeting of the 200-kW gas engine, because that engine is most suitable for ordinary buildings, including general offices, hotels, hospitals and department stores. The project is also targeting the production and installation rate of 100 units per month. It is estimated that there are 140,000 buildings in Japan that can adopt a co-generation system."

Based on View from Engine-Design Engineers

Since the second half of the 1970s, when he began ceramic engine development, Kawamura has always stresses this: "First of all, one must understand the true nature of ceramic materials. In the second half of the 1970s, an adiabatic engine was built with engine components made with one of the structural ceramic materials then under development; but the components fractured at a much lower value than that expected, based on strength test results with test pieces of the same material. As a result, many engine-design engineers gave up on the development. However, I realized that the ceramics fractured faithfully to its fracture probability, and the fault was ours for not thoroughly considering that probability. Also, it could mean that the engine builder was cheated by taking the material's performance test results obtained by a ceramics maker for granted."

In order to develop an adiabatic engine with many ceramic components, Kawamura says, "we believed it

necessary for a designer to go back to the material selection base, and we began to investigate just what kinds of ceramics are needed for the development." That was exactly why the word "ceramics" was added to the name of the research institute. Under that philosophy, the Isuzu team discovered a combination of silicon nitride ceramics that had a small friction coefficient, and it used the combination to produce a piston head and a cylinder liner. Kawamura describes his idea for the JGA project this way: "It is possible to reduce the cost one-tenth to one-fifth of the previous cost by subjecting a powder blend of inexpensive metallic silicon and silicon nitride to reaction sintering."

Conclusion based on Earnest Belief in Engine Evolution

The direction of Kawamura's initial development of ceramic engine was determined by the fact that he was "involved in advanced technology development for the purpose of improving diesel engines for automobiles."

Kawamura, in charge of engine design for the small truck Elf, one of Isuzu's major vehicle models, was transferred from the Design Department to the Development Center so that improvement could begin on the diesel engine's start-up performance. In those days, diesel engines required several minutes for start-up, because a heater had to heat the combustion chamber. The slowness problem was solved by the development of the silicon-nitride-based glow plug. The plug, with drastically improved heat resistance over that of previous heat-resistant alloys, made it possible to rapidly raise temperature by allowing the flow of large currents through it in a short time. Subsequently, the adiabatic engine with many ceramic components was created as a result of trying to find how to improve the diesel engine. The direct clue for the development of the adiabatic engine was the 1983 implementation of a silicon-nitride auxiliary combustion chamber in the Asuka model.

The key to the question—whether the ceramic engine will be a mere dream or will become a reality—is held in the palm of Kawamura. Ceramics- and engine-developers all over the world are closely watching Kawamura's moves. For example, he was invited to the international conference titled "The Fifth Conference on Ceramic Materials and Components for Engines," which convened for four days, beginning 29 May 1994, in Shanghai, PRC. In 1991, he had also been a guest speaker at a conference held in Sweden, and his lecture had been titled "Design Methodology of Engine Using Ceramic Components and Thermos Structure." The fact that the title begins with the word "design" tells us of the philosophy of Kawamura, a lecturer representing designers.

Hierarchical Structural Control to Develop High Strength, High Toughness Alumina

94FE0745B Tokyo NIKKEI MATERIALS & TECHNOLOGY in Japanese May 94 pp 62-66

[Article by Shuzo Kanzaki, Chief Researcher, GIRI, Nagoya, AIST]

[FBIS Translated Text] **The Government Industrial Research Institute, Nagoya, of the Agency of Industrial Science and Technology has improved the strength and toughness of alumina. Compared with existing alumina, the new alumina showed a room-temperature strength that was 1.4-fold greater and a fracture toughness value that was 1.7-fold greater. The development of the improved alumina, in which both strength and toughness were improved, would be considered a rare achievement anywhere in the world. It was accomplished with a new technique called hierarchical structural control. The technique is a technology for controlling the size and form of grain boundaries, pores, and crystalline grains in two or more hierarchical atom/molecule, nano, micro and macro levels. Without the use of any special device, the new technology makes it possible to simultaneously improve two properties that have been considered in a relationship of antinomy. In this article, the author will explain his thought processes and the actual techniques for hierarchical structural control to produce high-strength, high-toughness alumina. (Nikkei Material & Technology)**

Alumina (Al_2O_3) is regarded as the most general-purpose ceramic material. In fact, alumina is used in wide-ranging fields, including IC substrates, because of its excellent thermal stability, insulation capability, and corrosion resistance, in addition to the fact that it is comparatively inexpensive. Today, however, full utilization of alumina has not yet been achieved as a structural material. Compared with non-oxide-based ceramics such as silicon carbide (SiC) and silicon nitride (Si_3N_4), which are used for structural materials, alumina lags in high-temperature strength and creep resistance, although it has better oxidation and corrosion resistance. In addition, alumina's fracture toughness is poor, at approximately 3 $MPa/m^{1/2}$. Thus, alumina could not be implemented for structural materials because of these shortcomings.

If, however, alumina's strength and toughness can be improved simultaneously and made more reliable, the application of alumina to structural materials will undoubtedly be expanded. This paper will discuss the thought processes and the technique used to achieve the above-mentioned objectives. Needless to say, the technology to be presented in this paper does not limit its application only to alumina; it can also be applied to all other ceramics.

Impart Anisotropy and Minimize Flaws

Let us talk about the strength and toughness of a ceramic material consisting of isotropic, polycrystalline grains.

The strength of a brittle material like alumina is a function of both the size of the flaws in the material and its fracture toughness. For example, assuming that fracture toughness is constant (per linear fracture dynamics), the relationship between the flaw size and the strength can be expressed by the straight line I of the graph of Figure 1. If a material that has the toughness and strength values represented by point a in the graph is

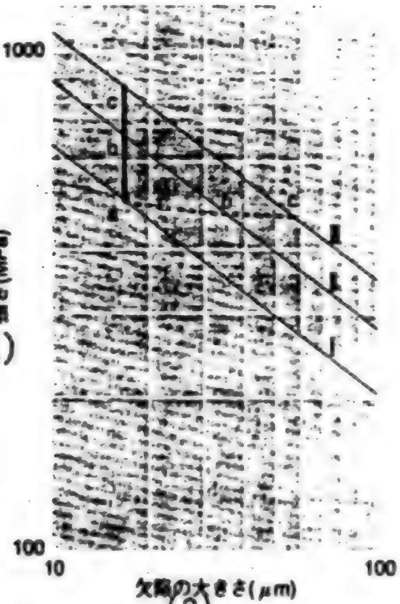


Figure 1. Relationships Between Size of Semicircular Surface Flaw, Strength, and Fracture Toughness (K_{IC}) of Brittle Material. K_{IC} is 3 MPa/m$^{1/2}$ for I, 4 MPa/m$^{1/2}$ for II, and 5 MPa/m$^{1/2}$ for III

Key: (1) Strength (MPa); (2) Flaw size (μm)

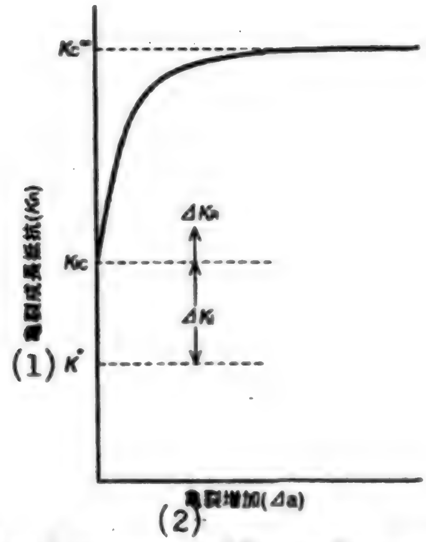


Figure 2. Improvement of Fracture Toughness by Second Phase. The increment δK_i is due to the mutual action between the second phase and the front end of a crack; and the increment δK_R is due to an increase in the material's resistance against the crack's growth.

Key: (1) Resistance against crack growth (K_R); (2) Advancement of crack (δa)

made tougher without changing the size of the flaw, the material's strength will increase, at least theoretically, in the direction of a→b→c.

In order to effectively increase toughness, one should disperse a second phase, which may be plate- or prism-shaped grains or may be whiskers with significant morphological anisotropy, throughout the matrix. When that is done, the toughness of the material will initially increase by δK_i due to the mutual action between the front end of a crack and the second phase. Subsequently, toughness will further increase by δK_R because the material's resistance against the crack's growth will be increased according to the ascending R-curve behavior[1] based on the cross-linking effect of the second phase when the crack advances. In other words, it is possible to improve the material's toughness by the sum of δK_i and δK_R by dispersing the second phase (Figure 2).

The second phase, which has been dispersed in the matrix to improve the material's toughness, can also act as a large flaw. As a result, the material's toughness is improved actually along the dotted line a→b'→c' in the Figure 1 graph, while its strength is decreased.

To solve this contradiction, i.e., to improve both strength and toughness, or to improve toughness while at least maintaining the same level of strength, one needs to satisfy the following conditions:

(1) alumina grains in the matrix, like the second phase, should also be made as morphologically anisotropic as possible;

(2) the second phase and alumina grains must coexist so that they mutually suppress the growth of the other phase.

In other words, two apparently contradicting phenomena must be simultaneously controlled by permitting the toughness improvement effect due to the morphological anisotropy to be manifested fully, while minimizing the flaw that is causing strength to decline. Such control of a material's micro-fine structure is the key to the improvement of both strength and toughness.

No Special Equipment Necessary

Once the goal is defined, one must choose a method of creating the target structure. Here, it is best to try to adopt as general-purpose a method as possible. For example, if non-oxide-based grains or whiskers are used, it will be difficult to calcine in air. In particular, if whiskers that can be densified only with difficulty are used, special equipment capable of creating special conditions, e.g., hot press or HIP (hot isostatic press), must be used. Even if a target material were obtained by using such equipment, the cost would be prohibitively high.

The author's group decided not to use any special equipment, but to first consider conditions conducive to

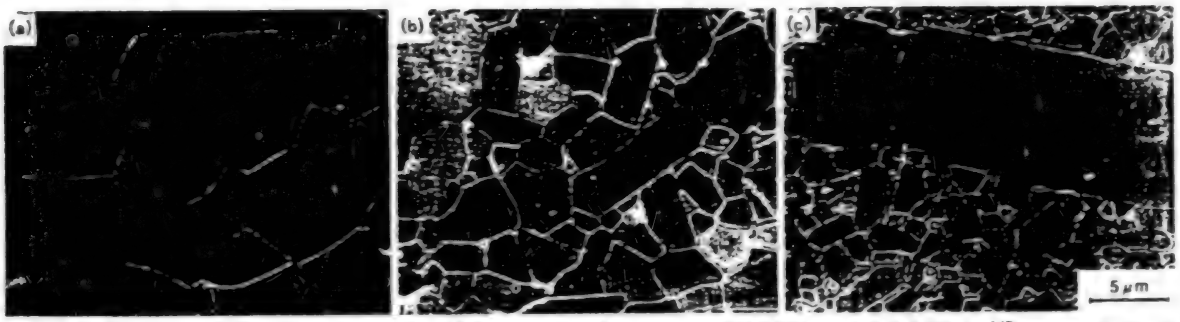


Figure 3. Structure of Alumina. Strength and fracture toughness were 430 MPa and 3.5 MPa/m$^{1/2}$, respectively, for high-purity Al_2O_3 (a); 470 MPa and 3.9 MPa/m$^{1/2}$, respectively, for Al_2O_3-250 ppm SiO_2 (b); and 410 MPa and 3.4 MPa/m$^{1/2}$, respectively, for Al_2O_3-600 ppm SiO_2 (c). The smaller the amount of silica, the greater its contribution to the improvement of strength and toughness.

easy calcination in air, and they chose oxide grains for the second phase to be dispersed in the matrix.

The next step was to screen a number of oxides to select the most suitable one. Here, we faced the dilemma that while it is more advantageous from the standpoint of toughness improvement to use grains that are as morphologically anisotropic as possible, it is more advantageous from the standpoint of density improvement to use grains that are as isotropic as possible. Oxides that can satisfy these contradicting conditions should be isotropic in their raw material stage, but should become anisotropic during the process of densification.

Lanthanum oxide (La_2O_3) was the oxide that could satisfy the conditions.

Actually, when lanthanum oxide was added to alumina, LBA (lanthanum-β alumina, $LaAl_{11}O_{18}$) was formed after reaction and showed anisotropic growth into plates.

Strict Control of Addition Quantity

As explained above, it is necessary that, along with the second phase, alumina grains in the matrix grow anisotropically during the sintering process in order to improve both strength and toughness.

Although alumina has a hexagonal crystalline structure that manifests crystallographic anisotropy, isotropic alumina grains are generally formed when its high-purity, micro-fine powder is sintered. However, when a certain material is added either to create a liquid phase that can coexist with alumina or to alter surface energy, anisotropic grains can be grown.

The author's group added a trace of silica (SiO_2) to alumina and successfully altered isotropic alumina grains into a plate form (Figure 3). Actually, it took the addition of only 250 ppm silica to alumina to make it anisotropic, and the resulting material showed a fracture toughness value of 3.9 MPa/m$^{1/2}$, which was 1.1-fold that of alumina without any additive.

However, when the added quantity of silica exceeded 300 ppm, huge plates of alumina were formed and grains surrounding the plates became smaller in size, causing the fracture toughness to decline. In addition, it is also necessary to strictly control the addition amounts of both lanthanum and silica because the addition of these materials tends to control the grain sizes of alumina and LBA. It is important to remember the following three points in actually producing alumina with improved strength and toughness.

First, a trace of silica must be dispersed as uniformly as possible. Second, the amount of silica must be accurately controlled by either knowing in advance how much contamination by extraneous silica will take place during the process or using a high-purity blending vessel to completely prevent the contamination. Last, since lanthanum oxide is highly hygroscopic, a compound such as lanthanum aluminate ($LaAlO_3$), synthesized from lanthanum oxide and alumina, should be used instead. With all these three points taken care of, the rest will be no different from the ordinary production process for alumina ceramics (Figure 4), except that the structure of the product will be considerably different from the usual one.

When alumina with added lanthanum oxide was precalcined, plate- like LBA grains grew in the alumina matrix (Figure 5a). At the same time, the size of alumina grains became smaller than their size without LBA (Figure 3a), although the grains maintained the cubic form. In contrast, when a trace of silica was added with lanthanum oxide, unlike when each of the additives was individually added, both the dispersed LBA grains and the alumina matrix grains grew to be plate-shaped (Figures 5b and 5c).

Improvement of Both Strength and Toughness

Let us examine the properties of the ceramics made by the above- described methods (Figure 6). Incidentally, the high-purity alumina to which the ceramics were

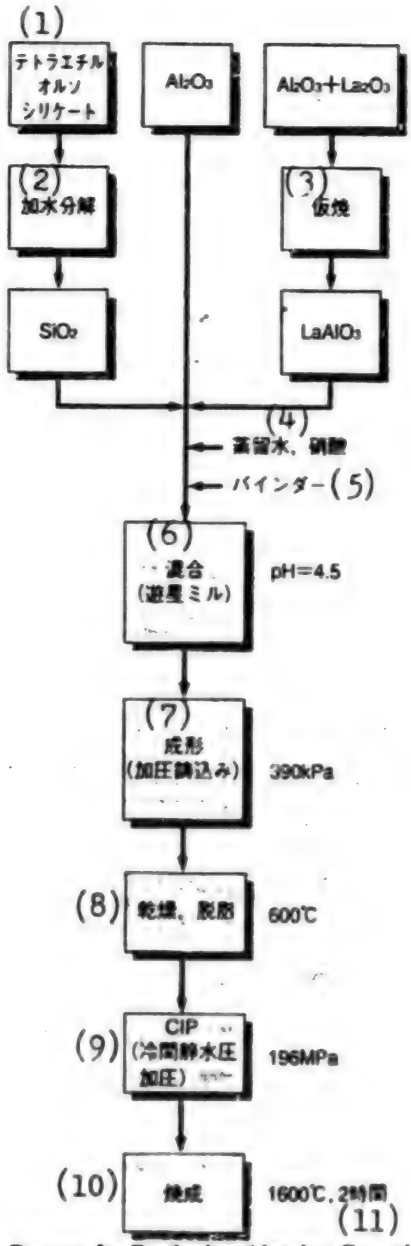


Figure 4. Process for Producing Alumina Ceramics. No special equipment is used.

Key: (1) Tetra-ethyl ortho-silicate; (2) Hydrolysis; (3) Pre-calcination; (4) Distilled water, nitric acid; (5) Binder; (6) Blending (epicyclic mill); (7) Molding (pressure-casting); (8) Drying, degreasing; (9) CIP (cold isostatic press); (10) Calcination; (11) Two hours

compared was found to show a strength of 430 MPa and a fracture toughness value of approximately 3.5 MPa/m$^{1/2}$ at room temperature.

Alumina, containing only the dispersed phase of LBA at a rate of 20-volume-percent, showed a greater strength of 670 MPa, approximately 1.6-fold that of normal alumina, although its K_{IC} increased to only 4.1 MPa/m$^{1/2}$, an increase of 1.2-fold. However, when a trace of silica was added with LBA, the ceramic material demonstrated simultaneously improved strength and toughness of 550 MPa and 6.4 MPa/m$^{1/2}$, respectively (Figure 6c).

Generally, it is believed that the high-temperature strength of alumina decreases when it contains an impurity, such as silica. However, it is not the case in these examples. At 1,200°C, both Al_2O_3-10 volume percent LBA-300 ppm SiO_2 and Al_2O_3-20 volume percent LBA-300 ppm SiO_2 were found to have strengths of 340 and 480 MPa, respectively, which were higher than 290 MPa for high-purity alumina.

These phenomena cannot be explained by simply compounding the alumina's property gains obtained by individually adding silica and lanthanum oxide. What appeared to be taking place after the addition of a trace of silica in the phenomena was a structural control process at a nano or smaller level involving either the formation of a liquid phase around each alumina grain or the alteration of alumina's surface energy.

Also, a micro-level structural control process was also happening at the same time in the form of the anisotropic growth of plate-like LBA grains. It is conjectured that as a result of these structural control processes, the simultaneous improvement of both strength and toughness, which had previously been considered to be impossible, was accomplished for alumina. Simultaneous structural control at two different levels of nano and micro is called "hierarchical structural control."[2] This concept will be further discussed below.

Imparting Two or More Properties

Functions and properties of a material are closely related to the types and structures of its components. In the case of ceramics, there are several structural elements, i.e., grain boundary, pore, crystal grain, and fiber, each of which exists with its own size and form (Figure 7). For the sake of convenience, the size can be expressed by "atomic/molecular," "nano," "micro," and "macro," whereas the shape may be sphere, plate, or prism, depending on the three-dimensional configuration, orientation, arrangement, and distribution.

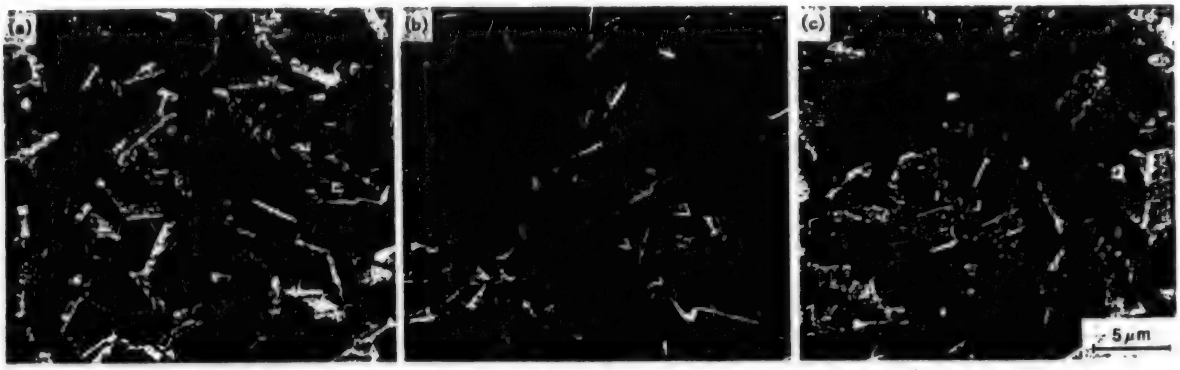


Figure 5. Structures of Alumina Ceramics with Added LBA and Silica. a: Al_2O_3-20 volume percent LBA; b: Al_2O_3-10 volume percent LBA-300 ppm SiO_2; c: Al_2O_3-20 volume percent LBA-300 ppm SiO_2. When silica was added, the second-phase grains, as well as the alumina grains in the matrix, became anisotropic. Here, the silica contents were determined by chemical analyses of the ceramic materials.

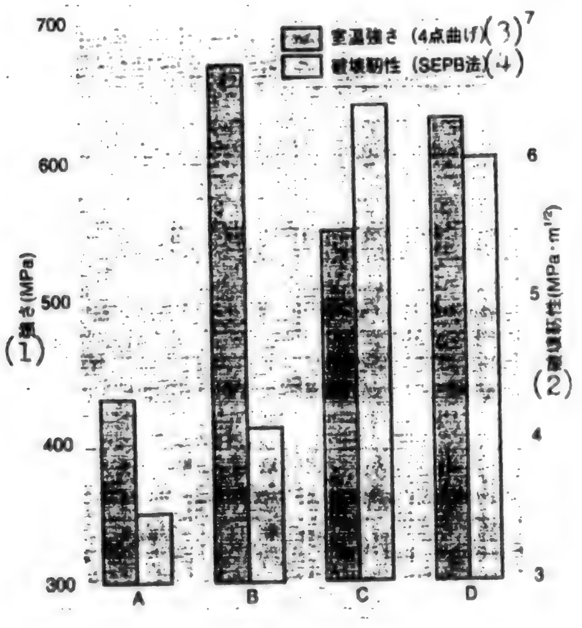


Figure 6. Strength and Toughness of Ceramics. A: Al_2O_3; B: Al_2O_3-20 volume percent LBA; C: Al_2O_3-10 volume percent LBA-300 ppm SiO_2; D: Al_2O_3-20 volume percent LBA-300 ppm SiO_2. Both strength and toughness were improved for C and D, in which both silica and LBA had been added. The SEPB method used for fracture toughness evaluation is the single-edge pre-cracked beam method, in which a macroscopic notch is made in a test specimen.

Key: (1) Strength (MPa); (2) Fracture toughness (MPa/$m^{1/2}$); (3) Room-temperature strength (four-point bending); (4) Fracture toughness (SEPB method)

Therefore, when one targets the manifestation of a given function or property by a material, it is important to control the size and form of each structural element at each level, in addition to the selection of the material's composition.

Previously, efforts of structural control were focused primarily on a single level. Although it was possible to improve a specific function of a material with this type of structural control, it was difficult to harmonize various properties to a high degree, or to simultaneously impart two or more functions to a material. In contrast, hierarchical structural control is performed with the realization that targeted properties and/or functions may be manifested at different levels. More specifically, hierarchical structural control aims at simultaneously controlling the sizes and forms of structural elements over two or more levels in a material by selecting other materials, including an additive that can be incorporated into two or more levels.

The structural control of alumina discussed earlier was performed merely on the basis of this concept.

Thus, a material capable of manifesting a plural number of properties and/or functions can be created by hierarchical structural control. Ceramics produced as a result of hierarchical structural control are called "synergy (or synergistic) ceramics."

It should be cautioned that one cannot expect all materials that have been subjected to hierarchical structural control to necessarily manifest synergism. Unlike metals and polymers, ceramics have diverse functions and many structural elements (Figure 7). Thus, it is likely that synergism can be expected more often from ceramics which offer so many more ways to perform hierarchical structural control, than from other materials.

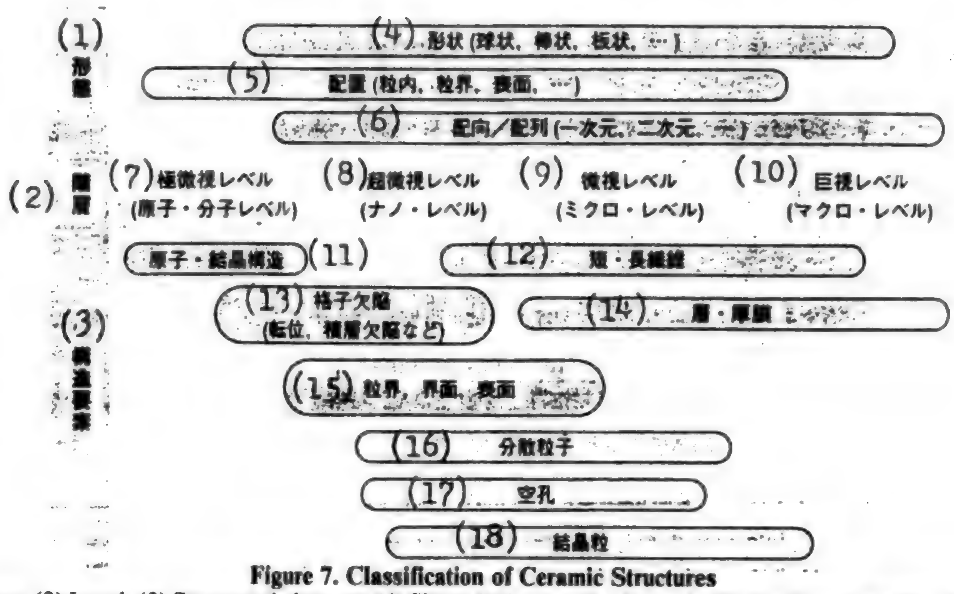


Figure 7. Classification of Ceramic Structures

Key: (1) Form; (2) Level; (3) Structural element; (4) Shape (sphere, rod, plate,...); (5) Configuration (inside grain, grain boundary, surface, ...); (6) Orientation/arrangement (one- dimensional, two-dimensional, ...); (7) Ultra-microscopic level (atomic/molecular level); (8) Super-microscopic level (nano-level); (9) Microscopic level (micro-level); (10) Macroscopic level (macro- level); (11) Atomic/crystalline structure; (12) Short, long fiber; (13) Lattice defect (dislocation, stacking fault); (14) Layer, thick film; (15) Grain boundary, interface, surface; (16) Dispersed particle; (17) Hole; (18) Crystalline grain

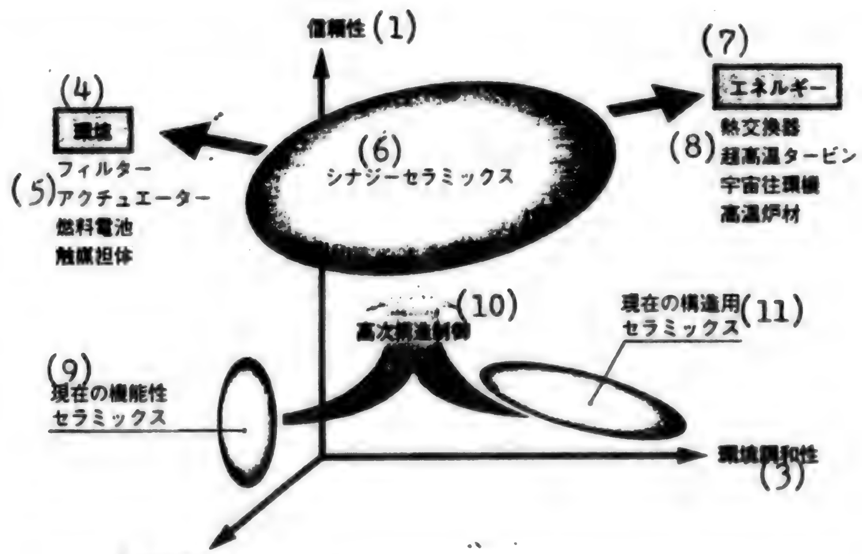


Figure 8. Synergy Ceramics Candidates for Hierarchical Structural Control

Key: (1) Reliability; (2) Poly-functionality; (3) Environmental compatibility; (4) Environment; (5) Filters, actuators, fuel cells, catalyst carriers; (6) Synergy ceramics; (7) Energy; (8) Heat exchangers, ultra-high-temperature turbines, space shuttles, high-temperature furnace materials; (9) Current functional ceramics; (10) Hierarchical structural control; (11) Current structural ceramics

For a starter, in its attempt to develop synergy ceramics, the author's group began to work on the symbiosis of strength and toughness. In the future, it is sincerely hoped that all kinds of synergy ceramics will be produced by incorporating various properties and/or functions, including thermal properties, electrical and magnetic functions (Figure 8 on page 25).

References:

1. Sakarai: "Fracture Dynamic Properties." "Ceramics Advanced Materials," pp 37-86, Oomu Publishing Co. (1991).

2. Kanzaki and Matsubara: "New Developments in Ceramics," CERAMICS, Vol 29, No 2, pp 124-130 (1994).

Suzuki Motor Co. To Develop Aluminum Engine

94FE0754A Tokyo NIKKEI SANGYO SHIMBUN in Japanese 12 Jun 94 p 1

[FBIS Translated Text] By autumn 1995, Suzuki will develop an aluminum engine for use in light-weight cars that will weigh one-third the weight of steel engines. The engines will be used in Alto and Servo Mode luxury cars, beginning in 1996. Aluminum engines are light-weight and offer excellent fuel economy. However, they're expensive to produce, so their use in light-weight cars has lagged because light-weight cars often tout their low prices. By using aluminum engines, Suzuki aims to gain market share in the light-weight market by displaying technological superiority over rivals such as Daihatsu.

The new engine is being developed with Aresty, a large manufacturer of aluminum parts. Suzuki is in charge of designing a three-cylinder aluminum engine for light-weight cars. Aresty is producing prototypes.

Steel automotive engines for light-weight cars generally weigh about 12 kilos. An aluminum engine is four kilos. At about one-third the weight of conventional engines, the aluminum engines will make cars run faster. Moreover, the engine mechanism can be improved and a closed mechanism can be used which will leave empty space around the cylinders which burn gasoline. This will improve cooling efficiency and reduce oil consumption.

Displacement is unknown. It will be determined with an eye to trends in their expanded regulation by deliberations between the Ministry of Transportation and the industry.

Suzuki is using an aluminum engine in Caltus, a passenger car with a displacement of 1,300 cc. However, because aluminum is expensive compared to steel, the engines' use in light-weight cars has lagged. Suzuki is taking the opposite tack. In its judgment, cars with aluminum engines will appeal to buyers because of their technological superiority.

Currently there are six manufacturers of light-weight cars. Only low- ranking Honda currently uses aluminum engines. The automotive industry believes that use of easily recyclable aluminum will spread among foreign countries tackling environmental problems.

Suzuki leads the light-weight car market leader with about 30% market share. Accordingly, its development of aluminum engines will probably start a trend toward wider use of aluminum engines in light-weight cars.

Nissan To Install 2000 cc and Smaller Lean Burn Engines by Year 2000

94FE0754B Tokyo NIKKEI SANGYO SHIMBUN in Japanese 1 June 94 p 1

[FBIS Translated Text] Nissan has decided to install lean burn engines by the year 2000 in almost all of its passenger vehicles with a displacement of 2000 cc or less. Installation is planned in some Sunny 1500CX cars which recently went on sale and in Pulsars which will undergo a full model change in 1995. Nissan aims to install the engines in eight types of vehicles as they undergo full model changes. This will lower costs by having parts in common with current engines. The product will combine lower cost and lower fuel consumption.

The following eight models will receive lean burn engines: Sunny (already underway), Pulsar, Bluebird, Primera, Precia, March, Abenil, and AD Wagon. The Cedric Gloria, Laurel, and Sefiro are 2000 cc cars, but Nissan seems to be focusing on cars with displacements of 1800 to less than 2000 cc.

As with the Sunny's GA engine, Nissan is turning existing engines into lean burn engines. The SR engine (used in the Bluebird and the Primera) and the CG engine (used in the March) will be the next lean burn engines as those cars undergo full model changes. The emphasis is on putting lean burn engines in the best-selling Sunny and Bluebird.

A lean burn engine improves fuel efficiency by increasing the amount of air used for burning gasoline. Toyota and Honda pioneered lean burn engines. By greatly improving the fuel efficiency of the Sunny's GA engine in conjunction with its full model change and by using lean burn engines, Nissan will produce a less expensive engine.

Other companies' car with lean burn engines typically cost about ¥100,000 more than cars with conventional engines. Nissan will hold the price increase to about ¥30,000 by using parts in common with its regular low-fuel consumption engines. Nissan figures it will reduce costs even further from production improvements that come from using lean burn engines in eight car models. Nissan's strategy is to avoid price increases while producing cars with low fuel consumption lean burn engines.

Hino Motors Develops Highly Efficient Large Diesel Engine

94FE0754C Tokyo NIKKEI SANGYO SHIMBUN in Japanese 19 May 94 p 1

[FBIS Translated Text] Hino Motors has developed and applied the world's most fuel efficient large diesel engine. In order to raise heat efficiency inside the engine, Hino used pistons made of a new material mixed with graphite, which is highly adiabatic and it also greatly improved the turbocharger. Heat efficiency improved 10% over existing large diesel engines. Improvements in heat efficiency not only make the engine more economical, they will also help the environment by reducing exhaust gases. Hino is currently developing 10,000 cc products, but it will also apply this technology to large and medium-size engines.

The newly developed P11C large diesel engine has a combustion efficiency (combustion efficiency is the means of measuring fuel economy) of 46%. Existing diesel engines have done no better than 43%. By improving combustion efficiency, the engine succeeds in improving fuel consumption without reducing output or torque.

The engine is first in the world to use pistons made of cast iron strengthened by graphite mixed with iron. Combustion chamber heat loss is reduced by use of this material which is more adiabatic than the aluminum alloy used in most diesel engines. Though strengthened cast iron is heavier than aluminum alloy, it is very strong, so the pistons can be made much thinner and smaller. The new engine's weight is almost the same as that of existing engines.

The high heat efficiency of the combustion chamber is accompanied by increased exhaust energy. Accordingly, a new turbocharger has been developed so the exhaust energy isn't wasted.

The turbocharger uses the pressure of exhaust gases to turn a turbine and to increase air intake into the combustion chamber. Formerly, turbine blades took the pressure from exhaust gases at a right angle. The new turbocharger has an improved turbine blade shape. It also uses an efficient diagonal flow turbine which gases hit on the diagonal from behind.

Hino has used this engine in some large trucks. Next it will use the engine in 13,000 cc and 17,000 cc large trucks and in medium-sized trucks under 10,000 cc. Hino will continue basic development since the characteristics demanded from the strengthened cast iron pistons vary with the trucks' displacements. Hino plans to install the P11C's new supercharger gradually in new vehicles. Hino is not considering external sales of its engine.

Charging Facility for EV To Be Installed at Regular Gas Stations

94FE0754D Tokyo NIKKEI SANGYO SHIMBUN in Japanese 12 May 94 p 2

[FBIS Translated Text] On 12 May 1994, an electric vehicle (EV) charging facility will debut at Showa Shell Oil's Noritake gas station in Nagoya's Nishi Ward. This is the first EV charging facility at an existing gas station to be created under the Ministry of International Trade and Industry's Model Project for Creating an Infrastructure for the Spread of Low Pollution Vehicles. This project to promote the spread of low pollution vehicles began in fiscal year 1993.

The charging facility uses evening-hour storage batteries and rapidly recharges light vehicles in 30 minutes. Its storage capacity allows it to recharge six light vehicles per day. It will operate from 8 a.m. to midnight.

There are already about 20 recharging facilities in Japan, but most of those are at electric utilities or local governments. They are also limited in voltage and electric current. The Noritake station will have recharging voltage of 48 to 500 volts and electric current of 10-to 150 amperes, making it practical for any EV.

MITI's Chubu Bureau took advantage of this occasion to announce that eight gas stations will add recharging facilities from May to June. Moreover, there are plans to open a CNG filling station, for natural gas cars, in one location.

Tokyo Electric Power Co., U.S. Company Develop Combustion System Reducing NOx

94FE0818C Tokyo NIKKEI SANGYO SHIMBUN in Japanese 1 Jul 94 p 1

[FBIS Translated Text] Tokyo Electric Power Co., Ltd. (TEP), jointly with General Electric Company of the U.S., has developed a system capable of reducing nitrogen-oxide (NO_x) generation by maintaining uniform temperature throughout the combustion chamber at a liquid-natural-gas-burning thermal power-generation plant. Previously, steam was added to the combustion chamber at an LNG thermal power-generation system to lower the temperature to reduce NO_x emissions. In the new system, air and fuel are pre-mixed, no steam is required, and the generated heat is utilized without waste. With the new system, cost reduction of as much as ¥1 billion can be achieved for each generator producing 1.4 million kW of power. TEP initially plans to install the new system for generators Nos. 7 and 8 at the Yokohama Thermal Power Plant and to sell the system to outsiders.

Today, the most efficient, improved, combined-cycle LNG thermal generators are being operated by 1,300°C combustion gas blowing on the rotor vanes of the turbine. The higher the temperature of the combustion gas, the greater the power-generation efficiency, unfortunately, accompanied by high NO_x emissions. At 1,300°C, theoretically 200-250 ppm NO_x are emitted by the generator without any additional treatment.

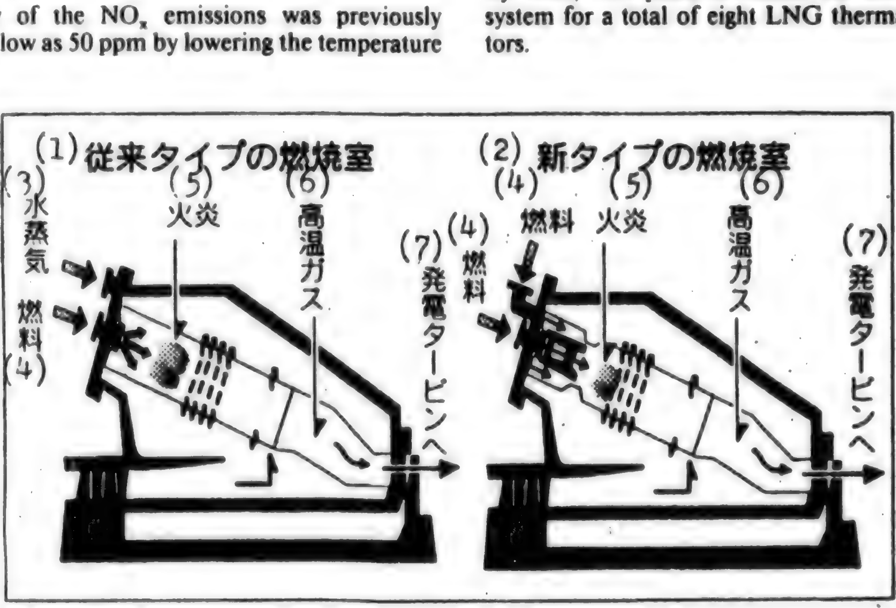
The quantity of the NO_x emissions was previously reduced to as low as 50 ppm by lowering the temperature of the combustion chamber by adding steam generated by the second-half process of the combined cycle back to the chamber.

However, this method annually required 1.5 million tons of pure water per generator, and the overall generation efficiency was only 2.6 percent because a part of the steam energy used to rotate steam turbines for the second-half process was diverted to reduce the chamber temperature. This steam energy loss was equivalent to a loss of 30,000 tons of LNG each year.

In the new system, not only is the pre-mixing done efficiently by spirally injecting fuel and air, but also the combustion is made as uniform as possible throughout the chamber by extending a part of the fuel injection nozzle to nearly the center of the chamber. The uniform combustion reduces NO_x generation substantially because NO_x is rapidly generated when unbalanced combustion creates localized high-temperature conditions in the chamber. As a result, the level of NO_x emissions was maintained at 50 ppm without the temperature lowering by steam.

The 50 ppm NO_x is passed through a denitration device to make the final emission of NO_x at a 5-ppm level. Thus, in addition to the cost saving in fuel and steam, the new system can use a pure water production plant of a much reduced scale with a construction saving of ¥2-3 billion.

By 1998, TEP plans to install the new NO_x-reduction system for a total of eight LNG thermal power generators.



Key: (1) Previous type combustion chamber; (2) New type combustion chamber; (3) Steam; (4) Fuel; (5) Flame; (6) High-temperature gas; (7) Generator turbine

ANRE Selects Sites for FY95 Unused Energy Utilization Demonstration Project

94FE0818A Tokyo DENKI SHIMBUN in Japanese 16 Jun 94 p 1

[FBIS Translated Text]

The Agency of Natural Resources and Energy (ANRE), MITI, has decided on sites for demonstration tests scheduled to start in FY95 in connection with the FY91 project concerning "Demonstration tests for the development of heating and cooling technologies for averaging power load in efficient utilization of unused energy." They are the Rinkai Sub-Metro-Center District of Tokyo, the Nanko Power Station of Kansai Electric Power Co., Ltd. (Kansai Electric Power), the Taremizu Sewage Processing Plant of Kobe City, and the Fukuoka Seaside Momochi district. The demonstration tests are to be carried out in order to build high-efficiency local heat supply systems for the purpose of promoting energy conservation and leveling off the electric power load. The test period is for three years, through FY98.

On 17 June 1994, the above sites will be officially designated for the tests at the meeting of the "committee for promoting the development of heating and cooling technologies to level off power requirement by efficiently utilizing unused energy" (Chairperson, Professor Ichiro Tanasawa, Tokyo University), which was established within the New Energy Development Organization (NEDO).

At the Rinkai Sub-Metro-Center District of Tokyo, waste heat generated by the cleaning plant and the transformer station, as well as the energy of sea water, will be used to supply heat to local heat-supply facilities, including the International Event Hall and the art museum, and to the pavilion hosting the World's Metropolitan Exposition. The following companies are expected to participate in that project: Tokyo Gas Co., Ltd.; Sanyo Electric Co., Ltd.; Toho Gas Co., Ltd.; Yazaki Corp.; Sumitomo Precision Products Co., Ltd.; Daikin Industries, Ltd.; Nichiban Co., Ltd. (Nichiban); Mitsubishi Electric Corp.; JGC Corp.; Shimizu Construction Co., Ltd.; Nippon Steel Corp.; Hitachi, Ltd.; and Toshiba Corp.

Either cold or warm water for the air-conditioning of offices will be produced at the station by the energy of sea water at the Nanko Power Station (with an output of 1.8 million kW exclusively by the combustion of natural gas) of Kansai Electric Power. Nichiban, Maekawa Manufacturing Co., Ltd., and Kansai Electric Power will be participating in the project.

Treated sewage will be used as the heat source at the Taremizu Sewage Processing Plant of Kobe City to produce both warm and cold water to supply heat to the management office building at the plant. Osaka Gas Co., Ltd., and Hitachi Zosen Corp. will participate in this project. Both Nichiban and Mitsubishi Heavy Industries, Ltd., will participate in the project at the Fukuoka Seaside Momochi district, where seawater will be used to support local heat supply facilities.

The demonstration test project, consisting of the above local projects, is being carried out by NEDO, which receives a subsidy from MITI, the Heat Pump Technical Center, and 19 private corporations participating in the project. In FY92, the project began with preliminary studies concerning:

(1) heat plants that utilize unused, low-temperature energy;

(2) heat plants that utilize unused, high-temperature energy;

(3) high-efficiency heat supply systems;

(4) plant optimal plan and operation system.

Japanese Institute Demonstrates Highly Efficient Waste Plastic Power Generation

94FE0818B Tokyo NIKKEI SANGYO SHIMBUN in Japanese 28 Jun 94 p 5

[FBIS Translated Text] The Plastic Waste Processing Management Institute (PWPMI) and Ebara Corp. (Ebara), have jointly confirmed the possibility of high-efficiency power generation through the tests of incinerating waste plastics including polyvinyl chloride (PVC). The cost of power generation was calculated to be ¥7 per kW, which was said to be cheaper than the cost of nuclear power generation. Upon incineration, PVC generates hydrogen chloride gas, which tends to damage the furnace materials. Therefore, many municipal governments have buried their plastic wastes. According to PWPMI, from the standpoint of effective utilization of resources, waste plastic can be safely incinerated if proper measures are taken.

Since the fall of 1993, three incineration experiments have been carried out for a cumulative time of 300 hours. The fluidized-bed combustion facility with a capacity of 30 tons per day at the Fujisawa Plant of Ebara was used as the incinerator. Waste plastics to be incinerated consisted of waste plastic blocks that had been processed to be buried underground by Okegawa City, Saitama Prefecture.

As a result of the experiments, the joint team was able to achieve a boiler efficiency of 87.1 percent for the recovery of steam from the combustion heat and a generation efficiency of 19.1-19.9 percent for the conversion of the steam energy to electricity. Computation based on zero fuel cost yielded the power-generation cost of ¥7 per kW, which was lowest of all the costs for currently implemented power-generation methods.

The joint team confirmed that the potential problems of air pollution and damage to incinerators by the combustion of waste plastics including PVC could be solved by the use of bag filters. The exhaust gas was found to

contain less than specified amounts of smoke dust, nitrogen oxides (NO_x), sulfur oxides (SO_x), hydrogen chloride, and dioxin.

The team observed little or no adhesion of clinker (glassy material of molten silicon dioxide) to the incinerator walls.

Many municipal governments, including the Tokyo Metropolitan Government, classify plastics in the category of "non-combustible wastes" and collect them separately for underground disposal, thus, avoiding incineration. If plastics can be incinerated, waste processing plants can operate longer, and petroleum resources can be effectively utilized. In other words, the incineration of plastics is the technology of killing two birds with one stone. Thus, the technology should draw the attention of waste processing administrators.

Mitsui Sekka Ltd. Develops Smallest Green Laser

94FE0871A Tokyo KAGAKU KOGYO NIPPO in Japanese 5 Aug 94 p 9

[FBIS Translated Text]

KTP Crystal Connects to the LD

Mitsui Sekka Ltd. developed a 30x28 mm^2 laser that maintains an outputof 30 mW and only weighs 35 g—a small fraction of the weight of conventional lasers of its kind. A KTP crystal, which is a wavelength converting element, connects to the large-output semiconductor laser (LD). That greatly simplifies the optical system, which becomes a factor that makes such lasers complex and large in size. The unit price of the laser ranges from ¥1-3 million. Mitsui Sekka guarantees a production capacity of about 1,000 units per year, and expects applications of the laser in fields such as electronics-related precision processing and measurement equipment.

In 1990 Mitsui Sekka tied up with Litton Industries, a U.S. company, and exclusively sold laser crystals from Litton Eatron, the synthetic crystal division of Litton Industries. In doing so, Mitsui Sekka built a top share of the market for laser crystals such as YAG (yttrium-aluminum-garnet) and KTP (potassium-titanate). Then, last year, Mitsui Sekka embarked upon downstream developments and used the YAG crystal in an 800-W high-output YAG laser device it developed.

With this new green laser, Mitsui Sekka succeeded in producing power with high efficiency along with wavelength conversion: a KTP crystal connects directly to the LD element to connect the optical axes for a laser device, that, in the past, had to be combined with several optical lenses to narrow down the beam. As the heat-radiating measure, the device incorporates a Peltier element, which is a thermoelectric-conversion material.

The volume of the new green laser is a small fraction of the volume of conventional products of its kind. The oscillation wavelength is 532 number, and the laser maintains an output of 30 mW in a single vertical mode. Mitsui Sekka is now evaluating the lifetime of the laser and expects that it can guarantee several thousands of hours of operation.

Mitsui Sekka set up a production facility with a capacity of of 1,000 units per year at the Sodegaura Research Center and has started opening up the market for its laser. Expecting uses for the laser in the repair of very small electronic circuits and in precision measurement equipment, the company is working hard to expand its sales.

AIST Will Begin Second Phase of Micromachine Technology Project in Fiscal Year 1996

94FE0871B Tokyo KAGAKU KOGYO NIPPO in Japanese 2 Aug 94 p 9

[FBIS Translated Text]

From Trial and Error, Issues Surfacing; First Phase Ends with the Development of Parts

MITI's Agency of Industrial Science and Technology (AIST) announced the results of the "MicromachineTechnology Project" that started in FY91. The national project on micromachines, said to be the only such effort in the world, has attracted attention since its inception, but the results announced this time were mostly about microparts having been made, and the development of micromachines is still a ways off. However, an AIST spokesman says that "after close to four years, we finally understand the problems," and from a period of trial and error, the technical problems have been clarified. With the second phase of the project slated to begin in FY96, micromachine development will enter into the now-or-never time.

Matsushita Research Institute developed what is calls a "micro-wobble motor" with a one-millimeter axis of rotation. The motor is driven by electrostatic force, but in the manufacturing technology up until now there was a limit to miniaturization. Because of that, general-purpose processing technology was used to finish the motor axis, then film processing and exposure techniques used in semiconductor fabrication were used to form inductive films and films that become the electrodes in concentric circles around the axis, and finally the films were fixed with a resin.

The researchers realized that they could easily control the rotational speed and they knew the torque value, but, as one researcher says, "Because it is the first time, even if we get a torque value, it has no meaning because there is no way to evaluate such a small motor." Thus, a system for evaluating micromachines does not exist. Now, the only way is to investigate the inconsistencies between the theoretical values and the values actually measured.

Although a good evaluation of the wobble motor has yet to be made, "phenomena unique to micromachines will come out of such evaluations, which should be called 'micro-engineering,'" says a spokesman from the Matsushita Research Institute. In micromachines, researchers confront physical phenomena unlike anything seen in our lives. For example, in a micro-environment, the friction arising from a motor's rotations becomes very large. That is why Nippondenso Co. developed a micromachine that uses a new method of

movement. The company succeeded in using a piezoelectric actuator to make the micromachine move in a tube like an earthworm, contracting and elongating, at a speed of 6 ml/sec.

It seems that different concepts are needed in the microworld. The torsional microvibrator with two degrees of freedom that was developed by the AIST National Research Laboratory of Metrology is also based on new concepts. The micromachine that was developed is a vibrator for sensors, and, unlike conventional vibrators, a large voltage is not needed to make the amplification large and thereby increase the sensitivity. The microvibrator is divided into an electrode plate and a movable plate and operates in such a way that a small deflection of the electrode plate becomes large in the movable plate. The microvibrator actively utilizes the "dynamic damping" that is most detested in machinery. It may also be called a reverse concept.

An epoch-making method was also used in the production of Nippodenso's micromachine. With the adhesives usually used in assembling parts, dimensional errors occur because of the adhesive layer. In addition, small screws cannot be made, and there is thermal damage in the joining of parts. Nippondenso developed a way to join parts using hydrogen bonds.

"A 'machine' is formed from the assembly of component parts. I would like to have a list of all the problems associated with assembly, and then develop a suitable device," says an AIST spokesman. At present, researchers are devoting most of their energy to developing microparts, but from now on the focus will shift to assembling those parts.

The issues of this project from now on will be 1) the technical evaluation of the devices, and 2) the problems associated with assembly. AIST researchers are eager to "solve those two problems during the second phase."

Tiny TCXOs Hold Key to Progress in Cultivating Miniature Portable Phones

43070206A Tokyo JEE English Jul 94 pp 30-33

[Article by Norio Yashiro, Toyo Communication Equipment Co., Ltd.]

[FBIS Transcribed Text] **Within the continually growing market for mobile communications equipment, demand for automobile, portable and cellular phones is expanding rapidly. The number of subscribers to portable phone services has grown remarkably because of the convenience of such phones. This market will continue to grow. Temperature-compensated crystal oscillators (TCXOs) serve as reference oscillators in the synthesizers for portable phones. Therefore, miniature TCXOs represent an important key to attain miniature designs for portable phones. Other trends also shape the development themes and prospects for TCXOs.**

Reference crystal oscillators for mobile communication stations use two kinds of devices, standard and digital TCXOs. Standard TCXOs use analog methods for temperature compensation, while digital TCXOs (D-TCXOs) use digital compensation. Analog TCXOs use direct and indirect temperature compensation methods, while D-TCXOs adopt only indirect versions (Table 1).

Table 1. Characteristics of Reference Crystal Oscillators for Mobile Communication Stations

Method	Temperature compensation method		Characteristics
Analog method	Direct TCXO	The temperature compensation circuit connects directly to the oscillation loop	It is possible to perform independent temperature compensation of low- and high-temperature sections. Simple circuit composition results in low price and is suitable for miniature designs.
	Indirect TCXO	The oscillation loop incorporates the temperature-compensation circuit that indirectly controls the variable reactance element.	Circuit is complex and requires a large number of components. However, it offers an accurate compensation.
Digital format	Indirect D-TCXO	The PROMs store temperature compensation data that undergoes digital-analog conversion, to control the VCXO as necessary.	The circuit is complex, but offers an excellent compensation accuracy.

Frequency Stability in Reference Oscillators

Different kinds of TCXOs offer different levels of frequency stability (Fig. 1). Most direct TCXOs attain a frequency stability of 1 to 5 x 10^{-6}, while indirect models have frequency stability ranges of 0.5 to 2 x 10^{-6}. Indirect-version D-TCXOs offer frequency stability levels from 0.05 to 0.5 x 10^{-6}.

History of Portable Phones

With progressive drops in the size of portable phones (Fig. 2), demand for miniature TCXOs has intensified. TCXO volumes have dwindled from 4cc in 1985 to 0.4cc. Thus the models today are 1/10 the size of their predecessors.

Miniature designs for TCXOs are important in devising small portable phones. Recently, manufacturers have been receiving accelerating demands for thin, surface-mountable TCXOs with low heights. In the future, after portable phone systems shift from analog to digital formats and from 800 MHz to submicrowave frequency bands, developers will have to make additional progress in miniature designs for TCXOs.

Outline of 0.4cc TCXOs

Initially, the car telephone system in Japan used a 25 kHz channel interval. However, service providers needed to augment the channel capacity, so they diminished the size of the channel intervals. Thus the system today uses 6.25 kHz interleave formats for the channel interval.

In the United States, service providers intend to decrease the channel intervals by introducing the narrow advanced mobile phone service (NAMPS) system. This system uses a 10 kHz interleave format, instead of the existing 30 kHz interleave format.

Most systems require a frequency stability of +/-1.5 x 10^{-6} across a wide temperature range. They also need small configurations, low power consumption, and excellent reliability. Various wireless systems must meet these strict specifications.

Direct-format TCXOs with 0.4cc volumes will satisfy strict requirements. These oscillators feature numerous advantageous characteristics.

To start, engineers use ultraminiature surface mountable devices (SMDs), including SMD crystals, to attain low heights of 3.5mm maximum. The structure of these devices gathers all the functional terminals on one side, enabling excellent productivity. Furthermore, they accommodate +3V driving. Fast rise characteristics accommodate intermittent operation of portable phones. Finally, these 0.4cc TCXOs deliver superior performance across a wide temperature range.

Specifications, Structures, Temperature Compensation Methods

Toyo Communication Equipment offers the TCO-976 series of 04cc-volume TCXOs (Table 2). These devices exhibit frequency-temperature characteristics of +/-2.5 ppm from -30° to 75°C. The frequency control range reaches +/-5 ppm or more at 2.5V +/-2V. Meanwhile,

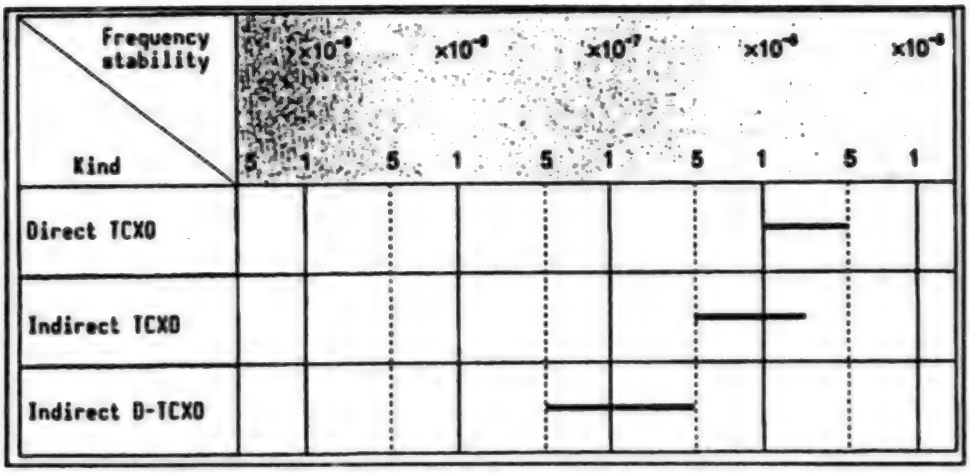


Figure 1. Frequency Stability of a Standard Crystal Oscillator

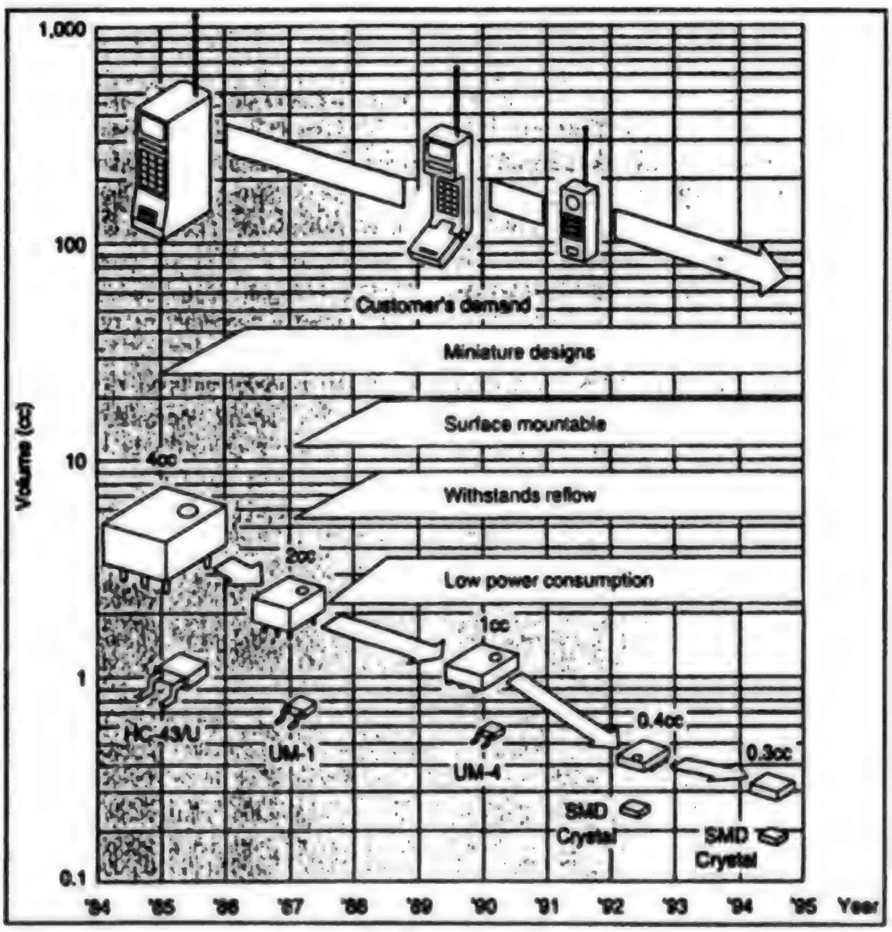


Figure 2. Trends in Miniature Portable Telephones, TCXOs and Crystals for Use in TCXOs

they accept supply voltages of 5V +/-5 percent. Within the TCO-976 series are versions offering 12.8, 13, 14.4 and 15.36 MHz as standard frequencies.

Table 2. The Main Specifications of the TCO-976 Series

Output frequency		12.8 MHz, 13 MHz, 14.4 MHz, 15.36 MHz
Frequency stability	Temperature characteristics	+/-2.5 ppm/-30 to +7.5°C (Reference temperature: 25°C)
	Power supply variation characteristics	+/-0.2 ppm/+5V +/-5%
	Changes with time	+/-1 ppm or less/year
	Initial deviation	+/-0.5 ppm/Vc = +2.5V, each = 25°C
Supply voltage		+5V +/-5%
Power consumption		2 mA or less
Output level		1Vp-p or larger, clipped sine wave
Frequency variation range		+/-3 ppm or more, with built-in trimmer
Frequency control range		+/-5 ppm or more, 2.5V +/-2V (positive polarity)

Besides offering compact external dimensions (Fig. 3), the TCO-976 adopts a fairly simple internal structure (Fig. 4). However, to develop an ultra-miniature TCXO with a 0.4cc volume, the engineers had to use several ultra-miniature components, including a tiny crystal resonator. Specifically, the TCO-976 series uses 7.8 x 3.4 x 1.2mm (D x W x H) SMD crystals, and chip components in the 1005 format (1 x 0.5mm). They also adopt trimmer condensers measuring 2mm φ, 1608-format thermistors, and 2125-format transistor modules.

The engineers developed SMD crystals exclusively for use in the 0.4cc-volume TCXOs. These crystals assure good heat tolerance and aging characteristics.

Furthermore, Toyo Communication Equipment holds a patent on the direct temperature-compensation method. Producing a simple circuit suitable for miniature designs, this method applies to the 0.4cc-volume TCXOs.

Key Points in Miniature TCXOs

Engineers and designers striving for miniature TCXO designs must keep several important issues in mind. Most of these issues involve the needs for miniature designs in the components and circuitry within the TCXO.

Miniature Crystal Resonator

The history of progress in developing miniature crystal resonators (Fig. 2) outlines the efforts to cultivate miniature TCXOs. Drops in the size of crystal resonators simplify development of small TCXOs. However, small resonators result in diminished Q values. In tackling miniature designs and using SMDs, engineers must consider countermeasures

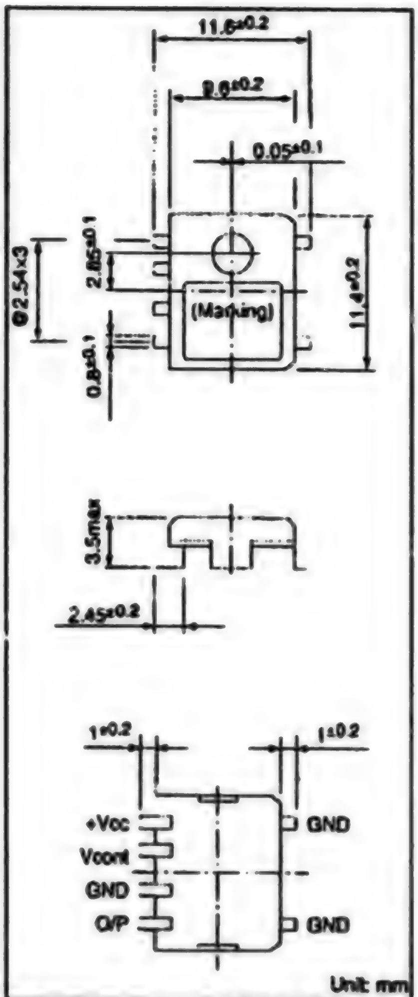


Figure 3. Dimensions of the TCO-976 Series

for the effects the support system exerts upon the vibrating region. It also is necessary to develop packages that are mechanically and physically stable.

Miniature and SMD Circuits

The tiny TCXOs that developers hope to cultivate will require small components, and even SMD components. This need includes items such as trimmer capacitors.

Use of Hybrid ICs

A look at the progress in cultivating miniature components (Fig. 5) simultaneously highlights the relationship between TCXO size and circuit component size. The first SMD TCXOs entered the market in 1989. Now, models with 0.4cc volumes are available. With existing technology, SMD TCXOs cannot withstand complete heat reflow soldering. Instead, manufacturers install these devices through spot soldering, using a laser beam or a blast of hot air to affix them in place.

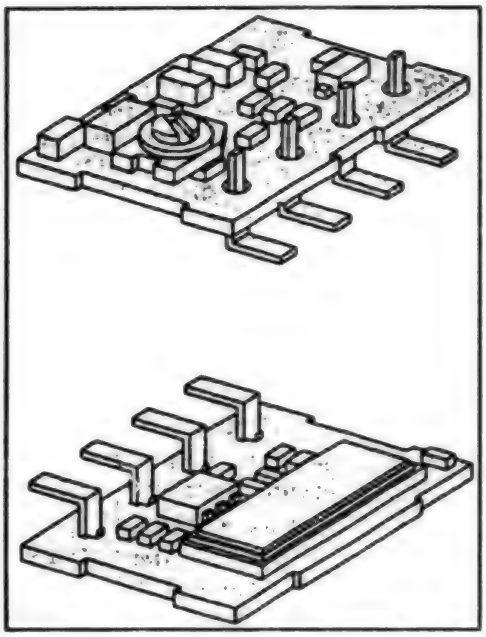


Figure 4. Structure of the TCO-976 Series

Figure 5. History of Changing Sizes of TCXO and Circuit Components

Configuration of TCXO	1985, 2cc, PIN format	1989, 1cc, SMD format	1992, 0.4 cc, SMD format	Future (0.2 to 0.3cc), SMD format
Crystal (cc)	0.13	0.072	0.032	Microcrystal
Transistor	Miniature mold	Superminiature	Ultra-superminiature	IC
DIP-RC	2125	1608	1005	IC
Trimmer (cc)	0.15	0.023	0.011	Trimmerless
Circuit board	Glass epoxy resin	Ceramics	Ceramics	Ceramic multiple-layer board
Terminal	PIN	Gull wing	Gull wing	LCC

As yet, no one has developed TCXO-use crystal resonators capable of withstanding heat reflow soldering processes. Crystal oscillators must offer excellent frequency stability. Nevertheless, demand for products that withstand reflow soldering is growing among manufacturers of electronic equipment.

TCXO Requirements

If TCXOs are to serve in the portable phones of the future, they must provide certain characteristics, such as small, lightweight designs. Thin configurations are particularly important. TCXOs also must assure heat tolerance against heat reflow soldering processes using eutectic crystal soldering. Product designs must take reflow soldering requirements into consideration. TCXOs for future use also must feature superior frequency stability, and must permit electrical adjustments to frequencies through an external controller. Manufacturers also will have to seek measures for low costs and will have to assure stable supplies of products.

Outlook for TCXOs

Those who make frequency synthesizers for portable phones are shifting to one-chip configurations incorporating phase-locked loop (PLL) devices and high-frequency analog circuits such as voltage-controlled oscillators (VCOs), mixers and amplifiers. TCXOs are indispensable: they constitute the heart of frequency synthesizers. Demand for these devices will rise in the future.

TCXOs serve in diverse markets including cellular telephones, cordless phones, and global positioning system (GPS) equipment. In 1993, 25 million TCXOs served in mobile communications equipment such as cordless phones, portable phones and car telephones.

Because of mass production and efforts to produce miniature models, the average unit prices for TCXOs have dropped annually. Prices for SMD TCXOs for portable phones have dropped dramatically. The most immediate demand from set manufacturers involves low prices. Thus the ways to cut prices represent important considerations for crystal manufacturers.

In the broad view of the TCXO market, it becomes apparent that manufacturers must develop LSI technology for active circuits. Such technology holds the key to developing TCXOs that assure high frequency stability and appropriate temperature-compensation characteristics.

Developers also must seek ways to cultivate TCXOs that accept low-voltage driving. Low-voltage TCXOs will contribute to the efforts to create miniature portable phones, because these oscillators enable the use of fewer battery sells than before. Low-voltage TCXOs further pave the way for the use of secondary batteries with large energy density levels.

Right now, the lowest driving voltage for TCXOs is about 3.5V. In the future, portable phones will accept battery driving, in a manner similar to pagers. Soon, developers will begin work on TCXOs that accept 1V driving supply voltages.

Fiber-Optic Access Networks and Services

43070206C Tokyo NTT REVIEW English May 94 pp 17-25

[Article by Tetsuya Miki, associate president, executive manager, Transmission Systems Laboratories, NTT; This paper is based on a lecture given at the NTT International Symposium '93]

[FBIS Transcribed Text] *If telecommunication carriers are to remain viable entities, they must construct sophisticated optical access networks based on FTTH. This paper discusses the fundamental issues for successfully implementing such networks. The basic concept of "Access Platform" is introduced to provide service-rich environments. A network image based on this concept is presented with an outline of systems requirements. Strategies for viable fiber deployment are discussed together with issues to be solved.*

Introduction

The 20th century has been a period of dramatic progress and development for the telecommunication industry which is preparing to play the preeminent role in a highly sophisticated information society. This century has only a few years remaining, yet it is predicted that during these years, a complete revolution will occur that will fundamentally reshape the telecommunication carriers.

Specifically, new carriers equipped with cable, radio, and other forms of media are looking for opportunities to penetrate local telecommunication services, hitherto regarded as the one natural monopoly of telecommunication carriers. Fierce competition is about to begin between these two forces, with the outcome being determined by the users. The key will be the ability to furnish extensive services at attractive prices.

If conventional carriers are to survive this competition, certain risks will have to be taken to build-up a communications network capable of providing the enriched services required by the users. One way of minimizing the risks is to introduce specialized systems featuring hand-picked services directed toward hand-picked customers. This, however, cannot result in services at reasonable prices over the long term and would fail to obtain the support of a diverse range of users.

The key to survival in this fiercely contested environment is to build up a comprehensive "optical access network" at the earliest opportunity. It is essential to establish a general purpose access system with minimal investment outlay such that conventional as well as new services on a trial basis can be furnished in a cost-effective manner.

There will be problems as one proceeds from the traditional metallic world to the relatively unrestricted optical world. However, these problems have to be overcome for telecommunication carriers to share the prosperous future with customers in the 21st century.

This paper discusses the concepts that can make optical access networks fully competitive with other media systems together with a system structure capable of furnishing an extensive range of services, specific methods of introduction, examples of new services and other related factors.

1. Access Network as a Service Platform

During the past century, customers have become accustomed to telephone service based on metallic cable and analog transmission technologies optimized for this cable. However, prospects now appear bright that the users will demand unique services that will assist in improving their living environment.

The problem lies in the fact that no one can predict what type of service will match these now latent demands. The principle for introducing any new service is starting small to test the market. The need is to minimize the costs of developing functional capabilities for access networks and initial capital investment for facilities. On the other hand, once success is assured, access networks will require flexibility in coping with rapid growth in demand, as well as meeting the users' whims which may necessitate certain changes in the services provided.

To satisfy the above requirements, the optical access network will need to furnish extensive access functions to the broadest possible range of existing as well as future services. Once this is accomplished, the introduction of a new service would merely require setting up a necessary server or service node at an appropriate location and connecting it to the access network. This allows the access circuit to respond immediately to any request and enable it to furnish any type of service. Access networks based on this concept will be referred to as the "Access Platform".

An access system equivalent to the access platform, must, of course, also respond in the conventional manner in supplying specific types of services. It must be capable of satisfying requests for single access links and multiple service circuits.

Introducing an optical access network based on the access platform will significantly enhance service variety and network operation as shown in Fig. 1. Further, it will provide telecommunication carriers with the tool they need to ensure their survival in the future.

2. The Optical Access Network and Constituent Systems

This section will introduce images of the optical access network and outline the systems constituting the network.

2.1 Transmission System and Service Nodes

Service nodes such as local switches and leased line nodes differ in demand density according to each service, and are therefore generally allocated to separate offices. The role of the access network is to provide the necessary number of circuits with the necessary capacity according to the demands between the service nodes and the users. To assure flexibility and efficiency in performing this task, transmission resources of the access network will need to be service intensive.

A specific access network image is shown in Fig. 2. It consists of two major sectors, the loop network and the transfer network. The loop network basically provides users with multiple circuit connections corresponding to the desired services through a single subscriber line that links the ONU (optical network unit suitable for the services desired) and the SLT (subscribed line terminal) set up on the office side. The transfer network, in contrast, uses paths

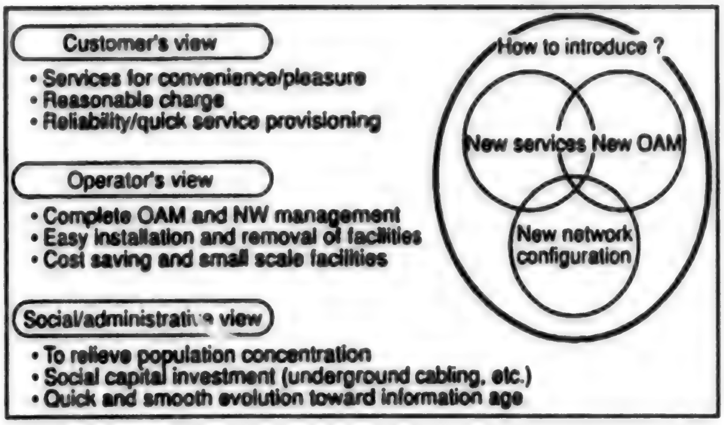


Figure 1. Future Direction of Fiber Optic Access Networks

between the XC (cross connect) and MUX (multiplexer) to provide the required number of circuits of sufficient capacity between the SLT and each service node. Thus, the SLT must offer the capability for grooming service circuits of differing types between the subscriber link and paths of the transfer system; therefore, the SLT must offer XC functionality.

2.2 Development of Three Types of Systems

A schematic diagram of the loop system is shown in Fig. 2. Various circuits allocated each type of service are multiplexed at the SLT according to the users' requirements. Toward the transfer system, the circuits are multiplexed into service groups. At the ONU, one line card for each service type is attached. Card installation is slot free due to the integration of the interface with the ONU main unit.

Eventually there will be no limitations regarding cost so a multi-purpose system can be introduced for all types of users. In practice, however, it will feasible to prepare a few discrete systems for the following two reasons.

First, the service mix and total capacity will vary with each customer. For example, major business users will frequently demand several hundreds of telephone lines

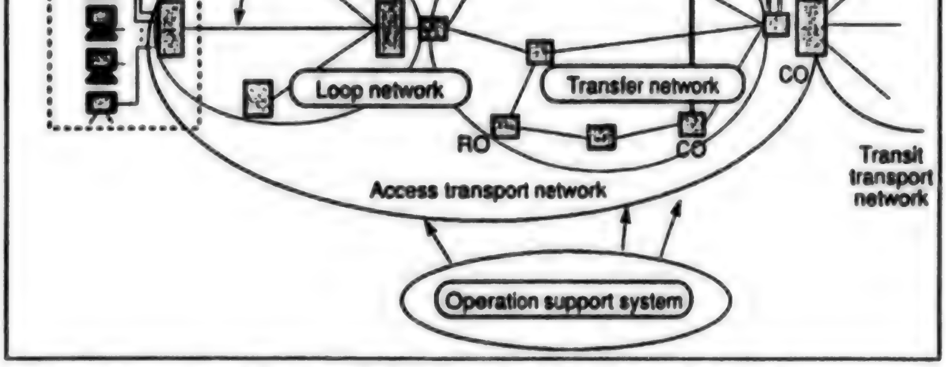


Figure 2. Network Architecture To Provide Multi-Services

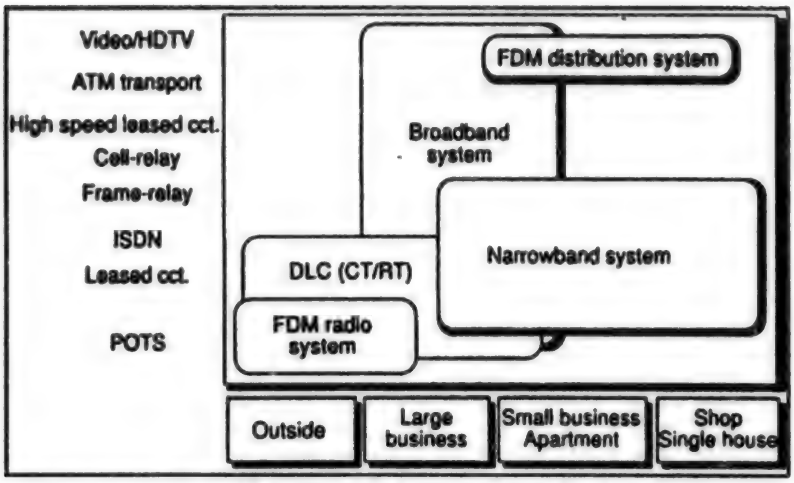


Figure 3. Fiber-Optic Loop Systems Line-Up

and other services including leased lines, packet and frame relays. In contrast, most household users are satisfied with a single telephone line and at most, ISDN service for the time being. It is more cost efficient, initially, to cover these two customer groups with systems of different capabilities.

Second, there is a difference between telecommunication and distribution services. Telecommunications is the basic service while distribution is an optional selection. It is basically unidirectional and requires huge downward capacity. Furthermore, there is the problem of support for CATV services without major changes in terminals or central systems. Coaxial CATV relies on the FDM scheme while telecommunications systems generally use the base band PCM scheme. Attempts at the simple unification of these modulation schemes will meet with difficulties.

After considering the foregoing factors, we decided to develop three different systems as shown in Fig. 3. Specific system structure is shown in Fig. 4. The narrowband system covers the requirements of minor scale customers such as small businesses, apartment houses, and residences in general. It provides telephone and an extensive range of narrowband services. This scheme, seeking to accommodate small users economically, relies on the PDS (passive double star) transmission scheme featured by optical couplers and TCM/TDMA (Time compression multiplexing/Time division multiple access). The broadband system handles mainly larger business customers and is capable of providing basically the entire range of current and future telecommunication services. This system uses ATM technology to guarantee flexibility in economically supporting various circuit types with differing capacities. The FDM system provides CATV and other distribution services and, in conjunction with WDM (Wavelength division multiplexing), can allow one fiber to simultaneously support both narrowband and wideband systems. This system uses the wideband characteristics of fibers to provide higher levels of services than is possible with coaxial systems.

2.3 Reliability and the Operations System

Conventional metallic cable systems are plagued by the high transmission costs. These systems fail to achieve adequate economy when duplexing or double routing is used to upgrade the level of reliability or to bring about improvements in maintenance activities. The optical subscriber system, on the other hand, offers low transmission cost through the use of optical fibers and high levels of circuit multiplexing. Duplexed double routing can be achieved inexpensively. This, in turn, realizes reliable and stable service quality.

The optimum operation scheme is essential if we are to realize enhanced reliability and to inventory numerous types of services. The operation system, shown in Fig. 5, can be classified into the facilities operation system which controls the access system and network resources on one hand, and the service operation system which controls service provisioning, customer data base, and related activities. These are set up as modules according to functions. Constituent units use standardized interfaces to simplify the addition, revision, or functional upgrading of each module. Introduction of the optical subscriber system would require, in addition to existing fiber cable facilities and operation system for switching equipment control, the installation of an access facilities operation system to supervise the facilities, circuits, paths, and other related factors. The main facility operation system would, of course, be connected via the data network to the service operations systems so that each operation could be followed up.

3. Deployment of the Optical Access Network

3.1 Mass Deployment Is Essential

Optical transmission technology has thus far been introduced mainly in transit transmission systems. To apply

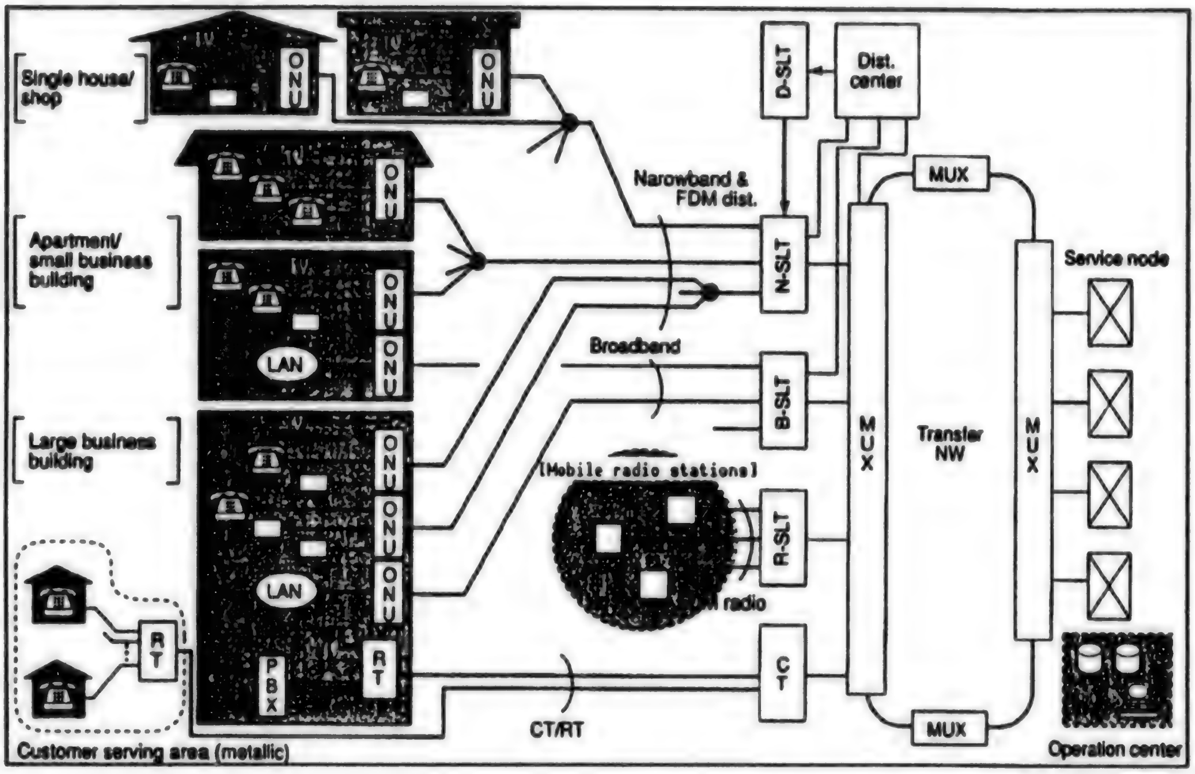


Figure 4. Fiber-Optic Loop Systems To Provide Multi-Services

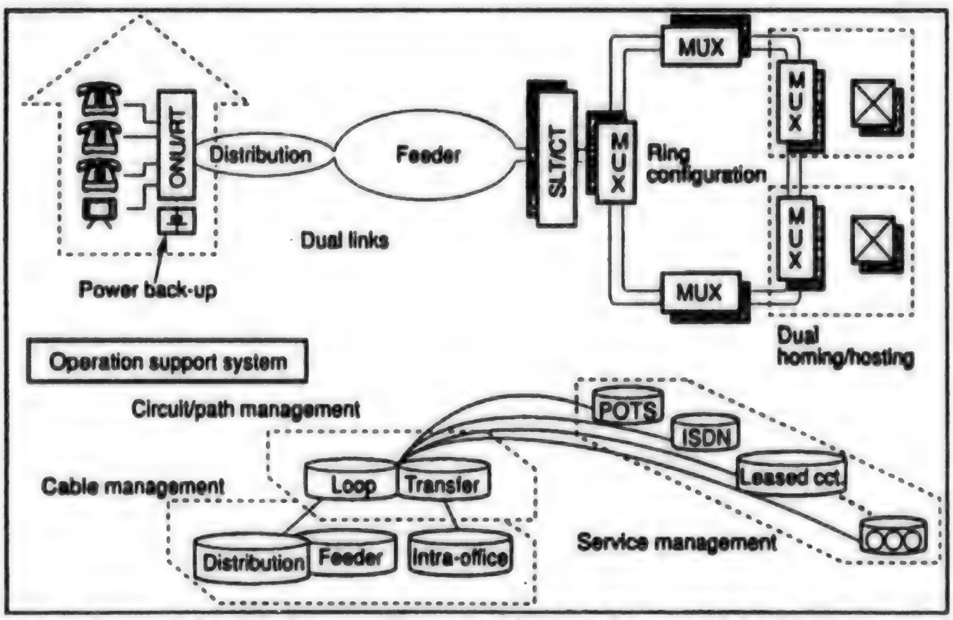


Figure 5. Fiber-Optic Access Network of High Reliability and Its Operation

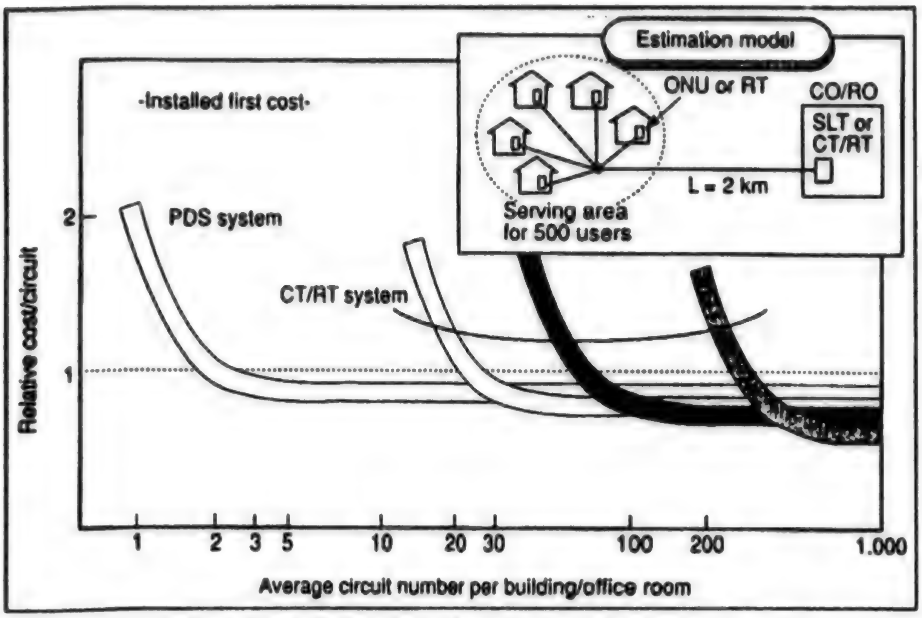


Figure 6. Cost Estimation (Area by Area Basis Deployment)

this to subscriber systems, there will be a need to realize massive economies of scale. This will, of course, involve technical development efforts but at the same time, economy of scale through mass deployment will be essential. The relationship between cost and mass deployment parallels the chicken and the egg conundrum. To break this quandary, it is essential to start with mass deployment. As shown in Fig. 6, if the deployment of 1 million circuit units can be assumed, a cost competitive optical subscriber system could be realized that would offer services down to the level of a few telephone circuits.

3.2 Two Options

Two options can be considered for introducing fiber into the subscriber areas. One is to deploy fiber after due consideration of service demand. The other is the planned replacement of metallic cables within different distribution areas by fiber. Figure 7 is an example of a trial calculation of the cost of fiber turnover for the entire NTT network. Assumed service demand is also shown in this diagram. Both options assume a complete conversion to fiber by the year 2015. As shown in the diagram, the latter option, area by area replacement, appears to be advantageous in terms of costs. In actual practice, there should not be just one alternative selected. It is wiser to select the option best suited to characteristics of the area concerned. For example, the latter option would appear superior for major business and commercial areas. For residential areas also, if distribution services such as CATV and other elements are to be provided, the latter option would be most suitable. On the other hand, in areas where broadband services are only sporadically demanded for some time, it would be advisable to proceed with conversion to fiber based on demand. In such cases, radio and HDSL should also be considered.

3.3 FTTH More Realistic

Many appear to regard FTTC (Fiber-to-the curb) as being more economical than FTTH (Fiber-to-the-home), but, in fact, it is the opposite. Adopting FTTH places the ONU (optical network unit) indoors so that requirements concerning strength and measures to counter lightning can be substantially mitigated. Further, the metallic cable on the terminal side is only 20 to 30 meters in length and the testing capability can be simplified. With FTTC, the need to upkeep numerous outdoor facilities would become excessive. These advantages of FTTH more than compensate any increase in costs due to the increase in the number of ONUS. Also, when considering infrastructure requirements for new services to be provided in the future, FTTH is far superior to FTTC. The logical conclusion is that FFTH [as published] should be adopted.

3.4 Criteria for Fiber Conversion

The foregoing sections discussed introducing fiber in fixed distribution units, the need for mass deployment and the inevitability of FTTH. There remains the need to discuss the policy of prioritizing fiber introduction.

When service demand is limited to a single telephone line, metallic cable appears to be more economical than fiber, but this is not true for grouped users. Fixed distribution areas will most likely contain apartment

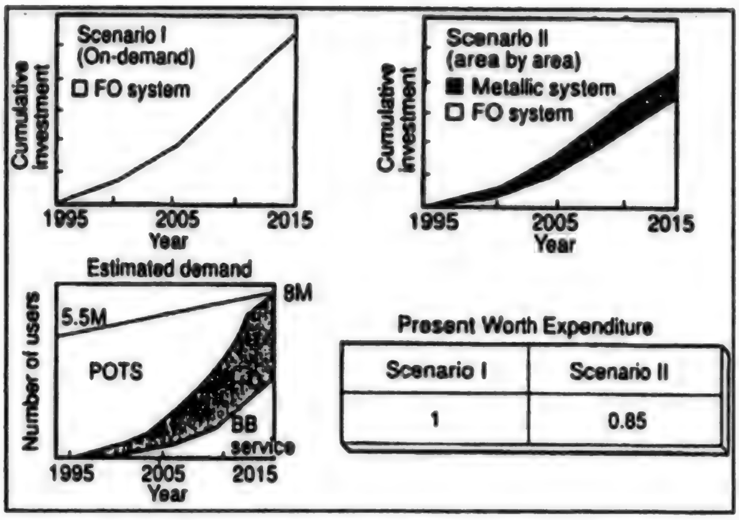


Figure 7. Deployment Scenarios and Macro Investment Estimation

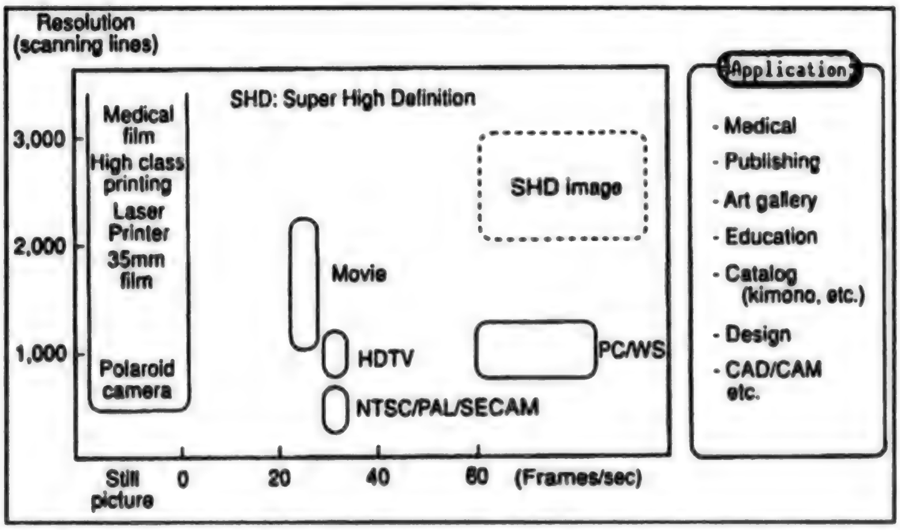


Figure 8. Example of Broadband Communication—Multimedia Communication With SHD Image

houses as well as institutional users. From the viewpoint of installing ONUs in buildings and offices, there are many fixed distribution areas whose demand averages several lines. This suggests that there will be many areas for which fibering is economical. In other words, fixed distribution areas can be analyzed in terms of the average number of lines per building and priorities should be set accordingly.

In residential areas, it is difficult under existing conditions to achieve economies with fibering. One interesting trend is the steady increase in the number of telephones per household (currently over 50% have two or more units) as well as an increase in the number of users with two telephone lines (currently about 10%). Growth in video services such as CATV is also predicted so it will become economically justifiable to fiber residential sectors in the future.

4. New Service Development

Optical subscriber lines have so many surplus lines that the costs incurred to supply additional services over additional subscriber lines are negligible. Therefore, once fibers are provided to a customer, he is ready to enjoy various broadband services coming up soon. One of very attractive services is SHD (Super High Definition TV) which would be a platform for many media such as newspaper, catalogue, TV, still picture, etc., as shown in Fig. 8.

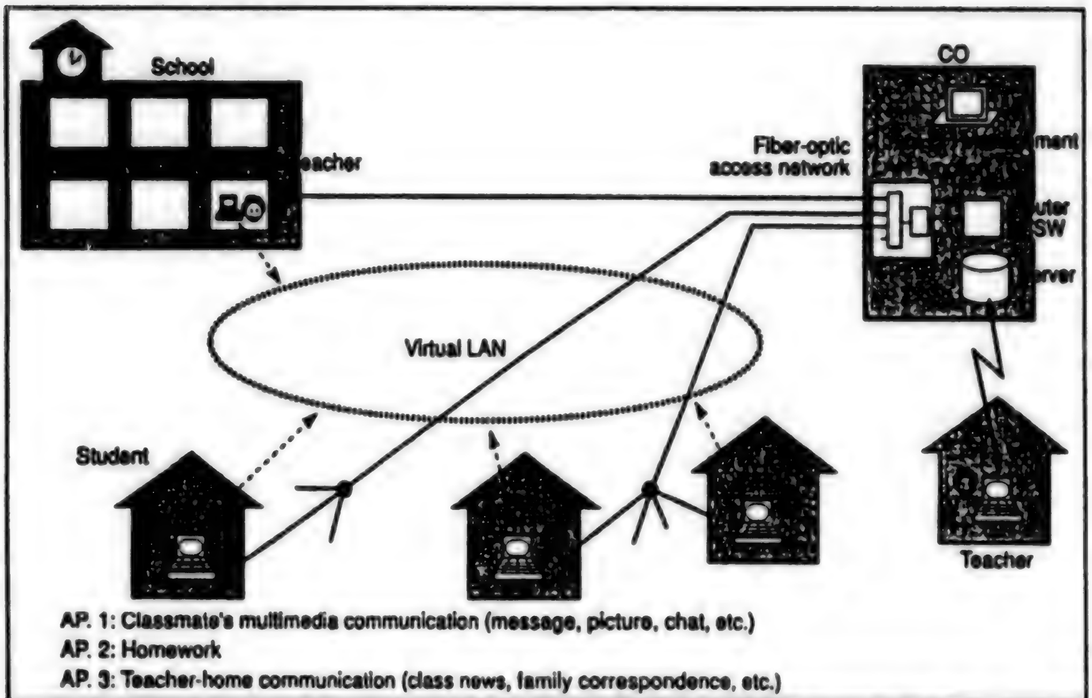


Figure 9. Example of Local Community Service by Virtual LAN—Group Communication for Education

Also, there is another possibility to establish new local services. Such an example is shown in Fig. 9. A LAN server is used to realize a Virtual LAN. As shown in the diagram, LAN services can be provided to a school teacher and the students in his class.

Another example is shown in Fig. 10. This is an image demonstrating data distribution service where data from news centers throughout the nation, and from household shopping centers and CD-ROM library centers, can be distributed through the local distribution point. At the distribution point, the data is multiplexed with image distribution and other pertinent information services and provided to local communities.

Local networks of the future will, in addition to the introduction of optical access network, be introducing ATM technology. This will make it possible to introduce new pricing schemes and to provide services attractive for both users and for those providing information.

5. Problems Requiring Solution

To realize the "Era of Multi-Services", the following issues will need to be studied in addition to the introduction of the optical platform.

The first point is the development of new attractive services. As mentioned in Section 4, optical access networks will provide abundant line capacities at minimal cost. The development of services that make full use of such facilities is essential.

The second point is standardization. Establishing an optical access network requires mass deployment to drive down costs as discussed in Section 3. To achieve further cuts in costs, worldwide standardization, particularly of the optoelectrical devices constituting the key to the system, are necessary.

The third point is deregulation. The progress achieved by technology has triggered intense competition between various media in subscriber areas. This has occur at the same time that the traditional fence between communications and broadcasting has been partially removed. To create the best possible environment for developing communication services, free competition is essential. Deregulation along these lines would be highly desirable.

The fourth point is security and reliability. The advent of the optical access network and other forms of powerful communication networks will bring about a sophisticated service environment. This will increase our dependence on communication in our daily social life. There will be a demand for high levels of reliability and security to protect. Technical developments are essential in this area also.

Conclusion

In order to support fully information-oriented society in the 21st century, where a wide range of viable communication services are available, the telecommunication carriers will need to establish optical access networks capable of providing a broad range of flexible services at reasonable cost.

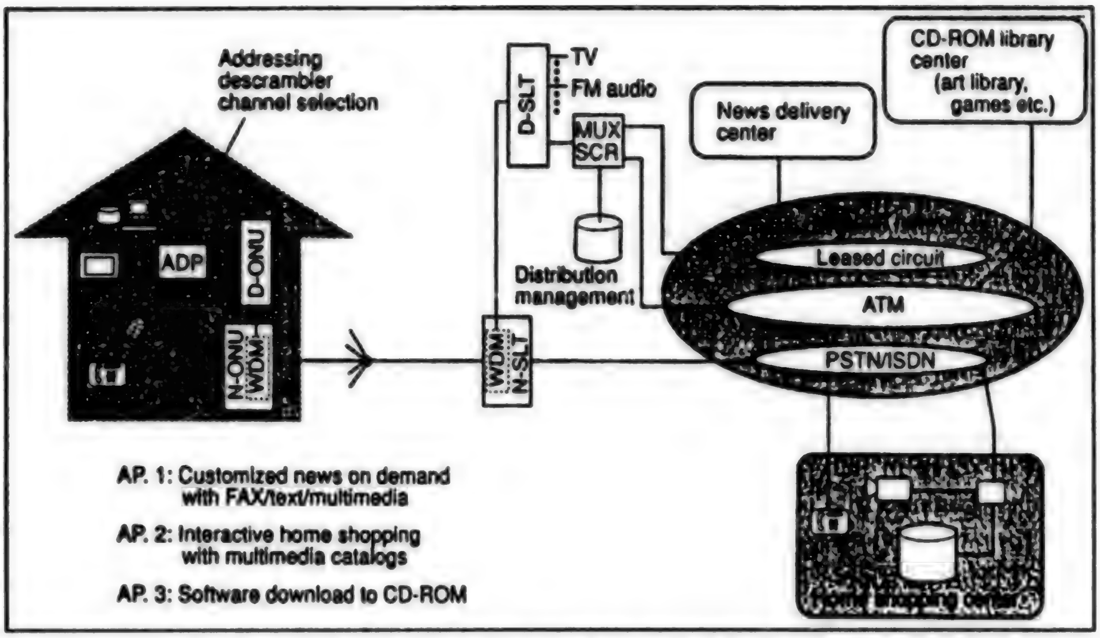


Figure 10. Data Distribution Service—Multimedia Information Distribution

This paper has discussed the access platform that is the basic concept for such optical access networks. We have outlined the three types of systems required for constructing such a platform.

Next, the paper introduced introduction scenarios for actual optical access network deployment, and clarified the necessity of mass deployment. The superiority of FFTH was clarified, and priorities determining fiber installation were discussed. Examples of new services and issues requiring solution were also outlined.

It is felt that through such discussions, the prospects for technical achievement and system cost reduction have been clearly presented to establishing optical access networks. We anticipate that construction work on a full-fledged optical access network will commence soon.

Overview of NTT's R&D

43070206B Tokyo NTT REVIEW English May 94 pp 8-16

[Article by Noboru Miyawaki, executive vice president, senior executive manager, R&D Headquarters, NTT; This paper is based on a lecture given at the NTT International Symposium '93]

[FBIS Transcribed Text] *With the ever-increasing importance of high-speed information in society as we move towards the next century, NTT is pressing forward with research and development aimed at implementing its VI&P (Visual, Intelligent and Personal) services and the construction of a new network to support them. In regards to the former, based on a long-term view of technological and market trends, NTT is researching and developing services that will make possible an effective progression from the development of services that answer to potential needs towards the full-scale implementation of VI&P services. In regards to the latter, we are responding in a flexible manner to the increasing diversity and dispersal of the communications environment by separating the network into a transmission system and a versatile information control/conversion system, and enhancing the performance of both. Within these broad aims, we are currently focusing our attention on three areas: the technology for a high-speed broadband transmission system featuring optical frequency multiplexing and ATM techniques, network and software technologies for advanced information control and conversion, and technology for constructing a new access network that can provide a comprehensive range of multimedia services.*

This article describes our concept of how VI&P services will develop in the future, and the latest trends in the field of communications. It also describes the ideal configuration of the new network and discusses the important technological aspects of how it is to be constructed. Finally, it presents the results of our recent research, which includes some innovative work, and points out the areas requiring future investigation.

Introduction

As the world stands poised at the beginning of a new millennium, a tide of change is sweeping through many areas. Telecommunications is no exception—indeed, this is a field which is being driven by fierce trends towards diversity and distribution, and in which technical innovation holds the key to its revolution. These trends have a decisive effect both on the way in which

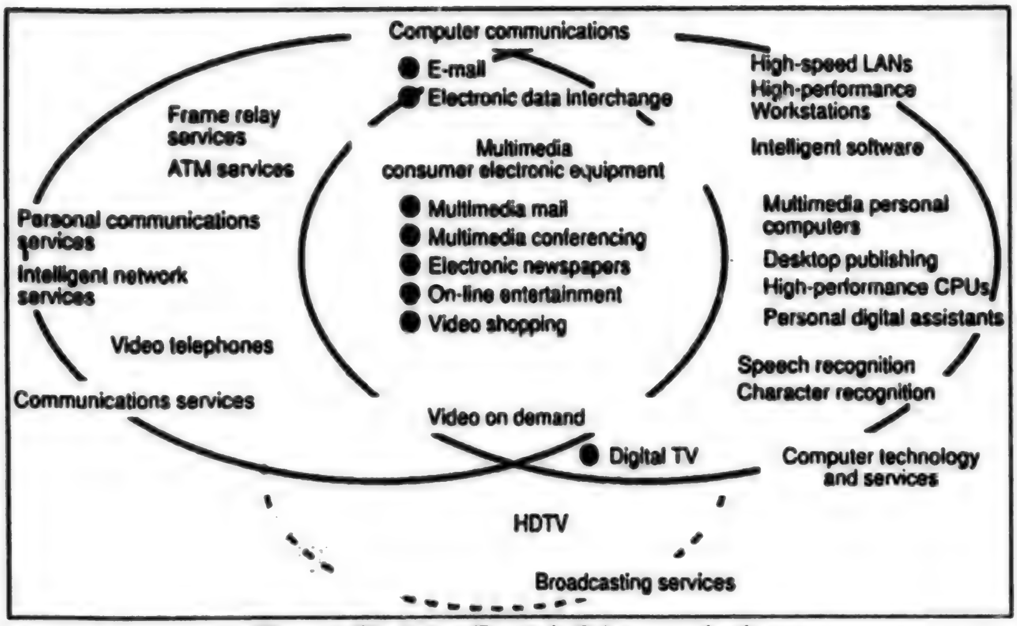


Figure 1. The Latest Trends in Telecommunications

new networks are introduced and on future technological trends. Furthermore, technological innovation is becoming a matter of utmost importance to communications carriers who are now being drawn into all-out competition with each other.

NTT is currently facing unprecedented challenges as a result of the prolonged economic recession and intensified market share competition. However, in spite of these circumstances, we are also putting increased effort into our continuous pursuit of R&D based on a long-term perspective.

NTT's primary R&D mission is to make technological developments and innovative advances while maintaining sufficient flexibility to respond to any developments in information networks. For this reason, we are taking a broad view of the way in which new networks should be introduced. While providing sufficient physical performance such as high speed and wide bandwidth, it is also important to supply new services having potential needs and to respond quickly to a multitude of existing needs. Consequently, we are researching and developing the essential technologies, both hardware and software, with the overall aim of achieving "high speed" in all senses of the word. And as the foundation for technology that will revolutionize these information networks, NTT is involved in wide-ranging research of both innovative and fundamental areas. Furthermore, another of NTT's R&D missions is to make the results of our basic research available for scientific, technological, and social development worldwide.

This document describes the targets of NTT's main R&D fields, and the key technologies required to achieve them. It also discusses the approaches that should be taken, and the likely effects on society as a whole.

1. NTT's VI&P Vision and New Trends in Telecommunications

The present-day communications environment (see Fig. 1) is having rapid and dynamic effects on society, economics and culture. This is reflected in the progress being made by ATM technology and high-speed LANS, the development of high-speed computer links, the rapid appearance of multimedia technology in personal communications devices, and the fusion of communications and broadcasting in "Video on Demand" services (particularly in the U.S.), to give but a few examples. With field trials of next-generation communications services scheduled to begin in 1994, the conception of the "Information Super-Highway" in the U.S. and the "Next-Generation Communication Network" in Japan, plans for global-scale portable phone networks using satellite technology, and the active internationalization of communications carriers in all countries, the above trends are growing to influence behavior not only at the national level, but also on a worldwide scale.

Major trends such as these are helping to clarify the routes by which VI&P services will be implemented, and are accelerating the communications revolution. In the future, competition for the development of fundamental technologies and ongoing development of applications in joint testing programs should lead to expanded media, faster and easier information processing, and improved mobility of communications services. It is important to establish promptly a service image that is directly related to these developments.

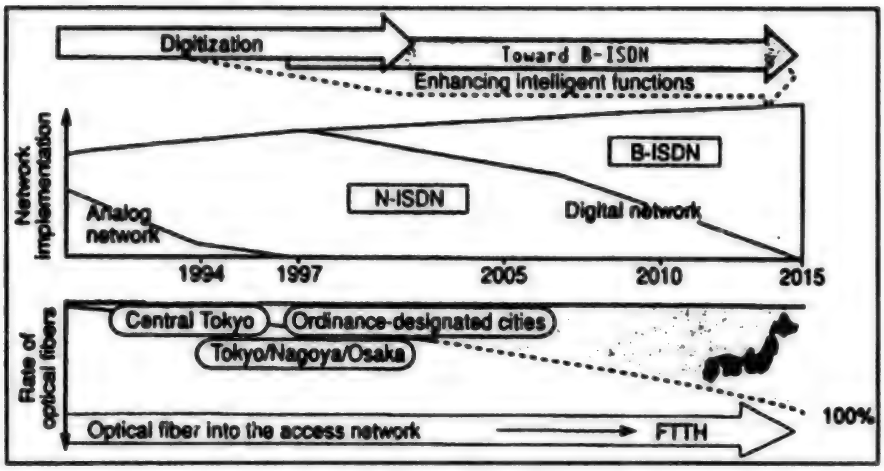


Figure 2. Future Network Evolution

2. Network Evolution and Key Technologies

A prerequisite for the expansion of future multimedia services is the construction of networks that can effectively and flexibly utilize the wide bandwidth of optical fibers in order to cope with a quantum leap in data transmission rates. For this purpose, NTT is working at converting to digital networks and B-ISDN, enhancing intelligent functions, and introducing optical fiber into the access network, as shown in Fig. 2. This move towards digitization is not merely driven by consumer demand, and we plan to have finished it by 1997. By 2015, we will have constructed an extensive network that can communicate video, speech, data and other multimedia information at ultra-high speeds with the sense of "being there." To achieve this, it is essential to make further advances in optical frequency multiplexing and ATM switching technology, and to improve the performance of service software. We have already established fully-optical trunk lines between the major cities of Japan, and we are proceeding with strategic conversion from metallic wire to optical fiber within the cities themselves, starting with central Tokyo and then moving on to greater Tokyo, Osaka, Nagoya, and other cities designated by the government. By 2015, we expect to be able to offer VI&P services to every household. Such "fiber-to-the-home" (FTTH) services presume the existence of a fiber-optic access network. This will be achieved by developing systems to respond to the scale and temperament of the market, constructing an access platform to support a complete range of services, and maximizing the efficiency and reliability of each system. Our research and development will cover all these areas.

The following section outlines the chief technologies required for the transport layer, access network and intelligent layer, and the efforts NTT is making in leading-edge basic research to contribute to these innovations. It also discusses the progress of our VI&P experiments incorporating the very latest B-ISDN technologies, and the way in which future networks will be introduced.

3. Transport Layer

For the construction of the B-ISDN, new technological breakthroughs must be made in switching and transmission systems. This section describes NTT's targets and achievements already made in the technologies for optical switching and high-speed optical transmission in the transport layer.

3.1 Optical Switching Technologies

As optical communication becomes more widespread, more and more users will require increasingly vast amounts of information to be transmitted. In order to achieve our long-term goal of providing a 150-Mbit/s VI&P service to every household, it will become essential to use "optical" nodes, in which switching is done directly on the optical signals. Consequently, one of the most important breakthroughs clearing the way for B-ISDN is the development of an all-optical ATM switch with a throughput on the order of terabits per second.

Figure 3 shows the progression of optical switching technologies. The keys to development are advances in VLSI and optical interconnection technologies, and the development of photonic switching. Throughputs of 40 Gbit/s are currently available, these being achieved in systems that incorporate densely-packed high-speed LSIs, enabling them to operate at maximum speed. These systems are already at the stage of overall system trials. It is likely that the capacity of board-mountable switches will become much higher through advances in VLSI technology. As the throughput increases, a bottleneck is first likely to occur in the interconnections between boards due to the limitations of electronic technology. However, this problem can be resolved by

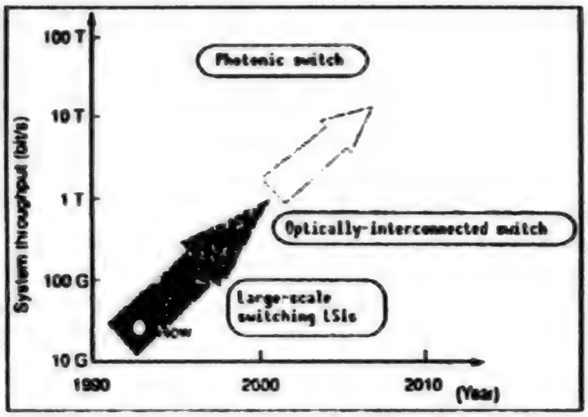


Figure 3. Progression of Switching Technologies

exploiting the wide bandwidth available for optical signals by means of high-density optical waveguides. That is, the first ventures into the terabit realm will be made by optically-interconnected ATM switches. By converting the switching elements themselves over to all-optical devices, throughputs in the region of 100 Tbit/s will become possible in the future. We are vigorously investigating ways of achieving closer fusion between spatial-division, time-division and frequency-division techniques that make full use of light's inherently wide bandwidth, high speed and parallel capabilities.

3.2 High-Speed Optical Transmission Technologies

With the aim of establishing an all fiber-optic network, NTT is continuing its installation of fiber-optic technologies into transmission systems. The progress made so far by optical transmission technologies is shown in Fig. 4. Higher speed and greater capacity have been achieved through the use of new technologies such as single-mode optical fibers, semiconductor lasers and optical fiber amplifiers. In addition, these technologies have contributed to a dramatic fall in the cost of communications. In the future, new technology will contribute to reducing the cost factors associated with distance and speed, making communications more economical. NTT's all-optical network will not only be characterized by such fundamental benchmarks as these, but also by simplicity of construction and flexibility of the services it provides.

Key technologies for all-optical systems will include optical frequency multiplexing, optical soliton transmission and ultra-high-speed optical signal processing. Here, we will introduce the results of the latest research in these fields.

Optical frequency multiplexing is a means of transmitting multiple optical signals through one strand of optical fiber at different wavelengths. It is currently possible to transmit 128 different wavelengths of light over long distances without using repeaters. Optical soliton transmission is a technique that simultaneously

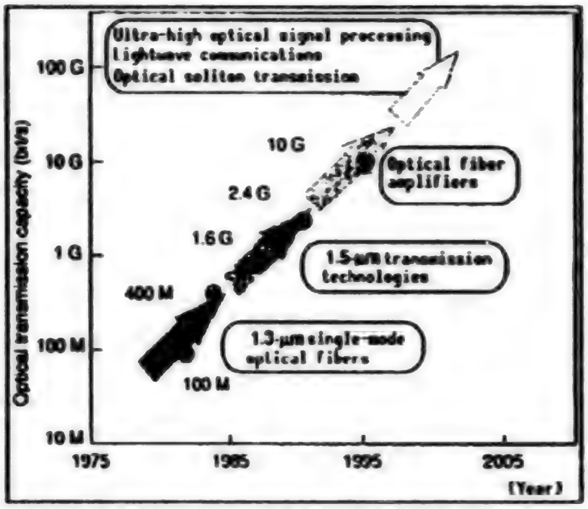


Figure 4. Evolution of High-Speed Optical Technologies

resolves the effects of both the bandwidth restrictions and the nonlinearity of optical fibers, and is being vigorously researched all over the world. At NTT, we have performed successful trial transmissions of 20 Gbit/s over 1,020 km without penalty using optical fiber amps as repeaters, and this technology seems to be ideal for achieving long-distance communications over thousands of kilometers without the use of repeaters. Furthermore, we have developed ultra-fast signal processing technology that makes it possible to transmit a 100-Gbit/s optical signal by optically multiplexing 16 different 6.3-Gbit/s signals together, and then separating them again. These results offer the potential of raising the technological level across the board, with ultra-short optical pulse generators, optical signal multiplexers and demultiplexers, optical timing extraction circuits, and so on. The above are examples of the special features of optical transmission by building upon serious investments in advanced technologies and breaking new ground.

4. Fiber-Optic Access Network

In order to offer the multimedia services envisioned for FTTH, the construction of an advanced access network is indispensable. If a reasonably-priced, user-friendly access system can be constructed and acceptable services introduced, it is expected that potential market needs will be awakened leading to a synergetic and rapid development of new services. "Access" may involve the use of optical fibers or radio means—in particular, a variety of approaches to the former method are currently being developed on an international scale. At NTT, we are investigating the construction of a highly reliable and economical optical access network based on the PDS (Passive Double Star) architecture. This section introduces some of our experimental work in this area.

The fiber-optic access network at which we are aiming will be introduced into offices and all kinds of areas, and then into the home, enabling customers to use a variety of services through one strand of optical fiber. It should also be possible for services to be added and updated without delay. To meet these requirements, the access network must be capable of establishing any number of circuits between the customer and multiple service nodes as needed. With this in mind, NTT proposes an "access platform" that offers wide support for all services and can be applied to B-ISDN as well.

The access platform is basically a mechanism for establishing links with the required number of circuits of the required capacity. It uses PDS transmission and multiplexing techniques to freely manipulate "paths" (the routes taken by circuits) through an optical link network.

The platform is currently based around STM technology, but we expect this will be replaced by ATM multiplexing techniques which have superior flexibility. Work carried out to set up the required number of circuits of the required capacity for each customer will be carried out entirely as remote operations by the operations center. As customers come to take full advantage of the fiber-optic access network based on these concepts, we can expect services to be used in more effective ways and more powerful software to be developed.

5. Intelligent Layer

The potential value of a network rises sharply as the quality of the services it provides is increased. Thus, future networks will not so much be implemented through physical changes to existing network constructions, but will be enhanced by incorporating more intelligent high-speed control of information flowing within the network. Consequently, those parts responsible for providing such capabilities must be separated from the transport layer and restructured to form an intelligent layer. This section first introduces the progress being made by advanced intelligent networks that give some idea of how advanced networks will operate. This is followed by a description of NTT's efforts towards software techniques that will form the core of the intelligent layer.

5.1 Advanced Intelligent Network

In order to reach the goal of providing and popularizing personal communications services and diverse customized services, NTT is progressing with research and development of advanced intelligent network services.

The basic characteristic of an advanced intelligent network is that its architecture is even more thoroughly stratified than that of other intelligent networks, forming a platform that does not depend on the services provided. Services are created and operated through the incorporation of diverse service software within this platform. As a result, it is not only easy to add or modify services, but it is also possible to control complex high-level services at high speed.

Advanced intelligent network services are not only for business use; they cover a wide range of possibilities for home and personal use as well. By adding communications processing features such as voice storage equipment, their ease of use can be greatly improved. It is also likely that the advanced intelligent network will grow to accommodate even more customized services, incorporating many types of composite services and multimedia communications.

5.2 Intelligent Software Engineering

NTT is researching and developing software production techniques from a wide perspective, pursuing everything from supporting today's large-scale software development programs to creating a new paradigm for the coming era of network computing. As regards the former, we have developed technology for preparing a computerized development support environment for each software development process in order to produce high-quality software effectively. Our progress in intelligent software engineering is an example of the latter, and is introduced below.

In software development, the fusion of two different technologies will become very important in the future. One is technology for acquiring user requirements systematically and accurately from what are usually vague descriptions. The other is technology for recycling portions of existing systems and applying the experience gained in earlier software development processes. To do this, existing systems must be analyzed and transformed into highly abstract representations in order to elucidate their essential functions. It is also essential to reproduce these functions in a suitable form for incorporation in the new system.

Assuming that software will generally be distributed over entire networks in the future, it will become very important to develop software that provides universally applicable functions while simultaneously answering to a wide range of needs. As our research into intelligent software engineering progresses, we will continue to put forward suggestions for new kinds of software in the age of network computing.

6. Basic Research

NTT's basic research is divided into six fields: photonics, intelligent information processing, media processing, nano-electronics, micromachines, and the search for new materials and properties. Pioneering results have been achieved in all of these fields. This section describes the latest results of our research into three of these fields—nano-electronics, photonics, and new materials/proper-ties—that are predicted to revolutionize network technology.

6.1 Nano-Electronics—Technology for Future LSIs

0.2-γm LSI technology is the next step beyond 0.35-μm, which is currently regarded as the "next generation" of process technology, and should become the mainstream

LSI fabrication technology around the year 2000. NTT has identified two key technologies that should bring about substantial advances in this area, and has succeeded in manufacturing a prototype 0.2-µm gate array.

The first key technology is synchrotron orbital radiation (SOR), which is electromagnetic radiation at wavelengths of 0.001 µm, one four-hundredth that of the ultraviolet radiation used in 0.5-µm LSI manufacturing. This technology has made tremendous progress in microprocessing possible. The second technology, developed independently by NTT, is the fabrication of ultrathin silicon layers on insulating surfaces. By using such thin films as circuit substrates, much higher processing speeds can be achieved. We have successfully developed a prototype 0.2-µm gate array that has one-tenth the cell area of 0.5-µm gate arrays, and consumes ten times less power. Using this 0.2-γm technology, it will be possible to implement the important functions of today's large general-purpose computers on a single 25mm-square LSI chip.

6.2 Photonics—Planar Lightwave Circuits

NTT is progressing with the research and development of optical devices and materials for the purpose of implementing an all-optical network (including "optical" nodes) supporting photonics-through-the-network. The main research areas here include planar lightwave circuits (PLC), optical semiconductor devices, optical fiber amplifiers, and nonlinear optical materials.

"Planar lightwave circuit" is a term coined by NTT to describe planar optical circuits consisting of optical waveguides on flat substrates. We have devised systematic and effective techniques for extracting particular features of light waves by carefully controlling their phase and interference as they propagate through low-loss glass waveguides. In other words, it has become possible to branch, couple, switch, separate, multiplex and demultiplex optical signals without having to transform them into electrical signals first.

PLCs are made using special fabrication techniques and advanced design methods. By combining the frame hydrolysis deposition techniques (as used in manufacturing optical fibers) with LSI manufacturing processes to produce highly advanced microprocessing techniques, we have made it possible to produce planar waveguides of any shape. Furthermore, by designing and simulating circuits on computer, we are not only able to propose new structural components, but we are also able to attain a much higher degree of accuracy at the design stage, contributing to the rapid creation of new products. We are also introducing computer technology into other areas of our research into parts and materials, as a means of increasing the efficiency with which advances are made.

The main products to which PLC technology is applied include large-scale starcouplers, thermo-optic switches and arrayed-waveguide-grating wavelength multiplexers. Such devices are contributing to innovative switching and transmission techniques. Furthermore, we are also researching active PLCs with optical amplification and nonlinear functions. PLCs make it possible to achieve higher densities, greater production volume and more diverse functions than are available with fiber components. It should also be possible to integrate them with optoelectronic ICs or organic materials, and consequently PLCs should make great contributions to the development of all-optical networks.

6.3 New Materials/Properties—Controlled Spontaneous-Emission Diodes

From NTT's wide-ranging research into new materials and new properties, our research into the field of quantum optics, which bridges the gap between new properties and photonics, has led to a revolutionary new device—the controlled spontaneous-emission diode.

Spontaneous emission, the basis for light emission, is not a universal property of atoms. This technology is based upon the concept that, by controlling electromagnetic fluctuations in a vacuum, we can change them artificially. This gave rise to the idea of producing wavelength-order semiconductor microcavity resonators and trying to control the electromagnetic fluctuations inside a vacuum. In order to improve the efficiency of photon confinement, the reflector above the microcavity is shaped as a microlens. This results in a laser oscillator with a threshold that is a thousand times lower than that of a regular semiconductor device.

The spontaneous-emission diode can output light with superior directionality, like a laser, at close to 100% quantum efficiency even when operating below its threshold value. This device should thus lead to the development of new light sources with incredible performance, such as ultra-low-threshold semiconductor lasers and single-mode LEDs.

In addition, NTT is investigating intelligent information processing techniques covering a wide range of fields from understanding human perception to autonomous distributed cooperation processing techniques that bear upon the implementation of full-scale networks. We are also looking into the innovation and integration of all kinds of media technology, and we are researching micromachine technology involving the miniaturization and fusion of advanced photonic, electronic and mechanical elements.

7. VI&P Experiments

NTT is progressing with comprehensive VI&P experiments by connecting its Musashino and Yokosuka R&D Centers to produce an actual VI&P environment. By incorporating the latest technologies into a single system, we hope not only to evaluate its benchmark performance under conditions close to those of actual use, but also to add finishing touches to the service functions. The experiment entered its second phase last year with the

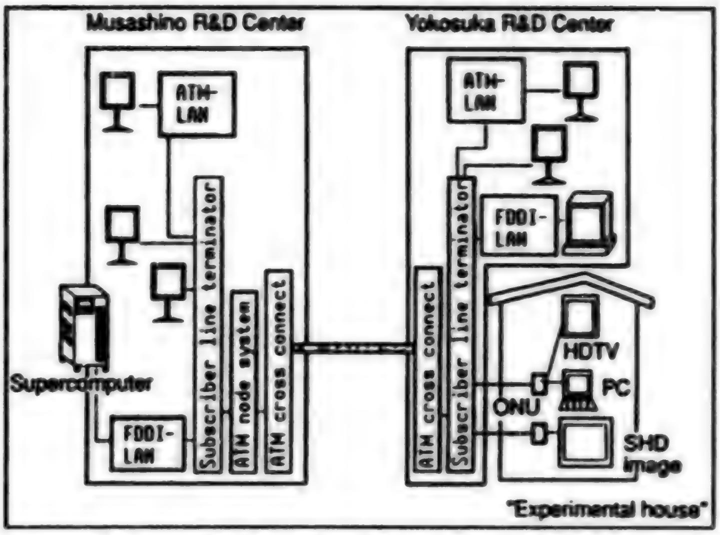


Figure 5. System Configuration of Comprehensive VI&P Experiments

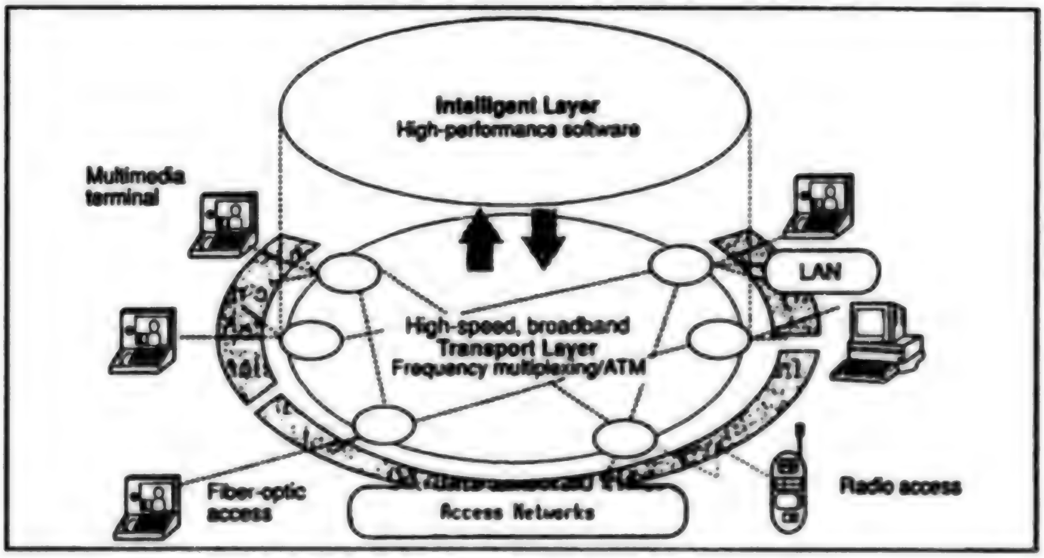


Figure 6. Envisaged 21st-Century Network

first tests of B-ISDN services, including advanced multimedia services and high-speed computer communications. The multimedia services are being tested using an "experimental house" constructed near the Yokosuka R&D center. This house is connected by an optical subscriber communications system which supports such services as an electronic newspaper and remote medical diagnosis by means of super-high definition (SHD) images with a resolution similar to that of 35mm film, and four times that of HDTV images. The house is also capable of simultaneously handling up to 60 high-definition TV channels or video phone circuits. On the other hand, our high-speed computer communications experiments involve transmitting high-speed data (45 Mbit/s) over a distance of about 100 km from a supercomputer in Musashino to Yokosuka via an FDDI-LAN and an ATM system. We are also experimenting with remote multi-party conferencing and LAN interconnection methods. In the future, we plan to test a wide range of services involving, for example, applications for public networks using ATM exchanges.

In the future, it is important for Japan to provide new services and develop new software in a strategic manner, and to take as much, advantage as possible of its advanced infrastructure. NTT's comprehensive VI&P

experiments are helping to establish how this infrastructure should be used, and are contributing to the services it will eventually provide.

8. Perspective for the Future Network

Toward the next century, we anticipate a functional division of networks between the transport layer and intelligent layer, with improved performance for each, and the significant progress of access networks. The network concept behind this perspective is shown in Fig. 6. Consequently, NTT's R&D will in the future place emphasis on optical frequency division multiplexing and optical ATM technology with their potential for making optimal use of the wide optical bandwidth, on the construction of an access network based on new concepts, and on improvement of software techniques as a basis for the evolution of new services.

With the ongoing enhancement and diversification of telephone services, the fusion of information processing and communications that is expected to take off in the late nineties, the expected high demand for visual services by the year 2000 and the evolution in multimedia services to handle them, NTT is now pursuing and will continue to pursue technological development and standardization in a wide rage of fields on the basis of its worldwide vision and anticipation of future trends.

Transfer of Crossbar Switching Systems for Reuse in China Completed

43070206D Tokyo NTT REVIEW English May 94 pp 26-30

[Article by Masaaki Kasahara, manager, Yasuhiko Marumo, director, and Shigeo Kubota, manager, all of the Technical Center, Plant Planning Department, Network Service Product Headquarters, NTT]

[FBIS Transcribed Text] *NTT has been transferring its used crossbar switching systems to the People's Republic of China at the request of Japan's Minister of Posts and Telecommunications to cooperate with China in modernizing its telecommunications network and to promote friendly relations between the two countries. However, NTT has now closed the transfer operation since China has come to the point where no further transfer of these systems is required due to the simultaneous digitization of its telecommunications network. This paper outlines the history of this transfer operation.*

Introduction

As part of its modernization plans, the People's Republic of China has been aggressively expanding its telecommunications network. In the autumn of 1982, Japan and China began discussions on the feasibility of China re-using NTT's crossbar switching systems which had been removed from service.

A number of technical problems were expected in implementing this reuse plan. These problems were studied in both countries, and certain solutions for them were found. Consequently, a memorandum was signed in 1984 between NTT and China's Ministry of Posts and Telecommunications. NTT then started transferring hardware and at the same time dispatched a large number of engineers to transfer the construction and maintenance technologies.

It is considered that the transfer of these switching systems has contributed significantly to China's telecommunications services and Chinese society. Local reports said that "the introduction of crossbar switching systems in the City of Datong raised the curtain for telecommunications development throughout the whole province."

Almost ten years have passed since that start. At present, NTT's switching systems are providing service in continental China in excess of 300,000 lines, and are highly appreciated because of their quality, performance and economy.

This report describes in some detail the history of this operation at the close of the transfer of crossbar switching systems to China.

1. Initial Facilities Transfer

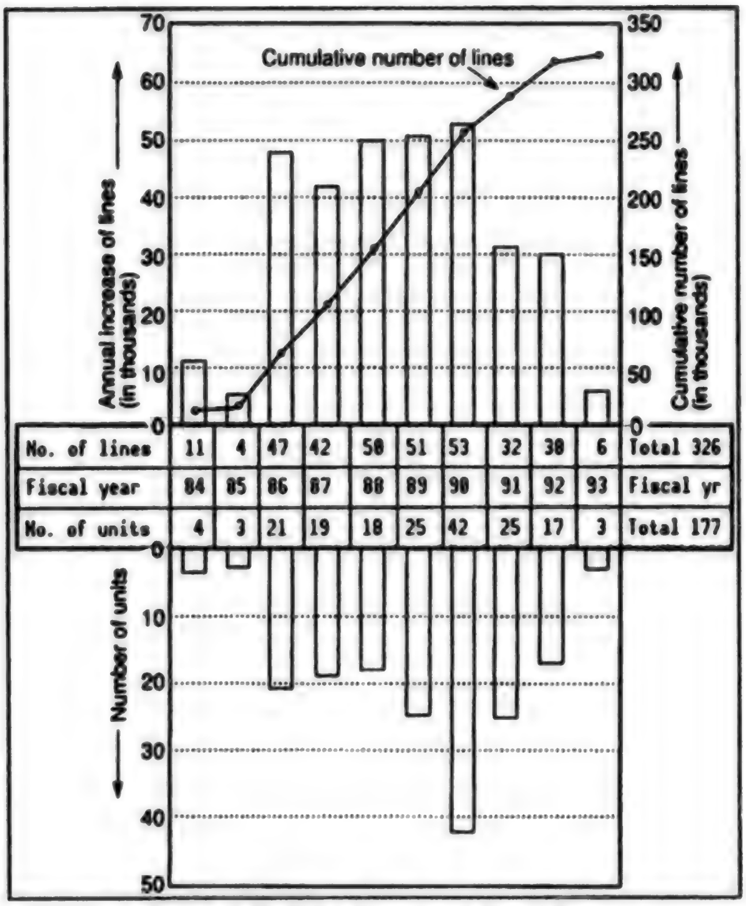
The transfer of crossbar switching systems began in 1984. Initially, it was in the form of a "testing room" installed in the Shenyang telephone facilities factory in Liaoning Province to verify technical measures, and as a "testing office" to provide commercial service by terminating actual subscriber lines in Datong Office, Shangxi Province.

While the testing room was under construction, China's Ministry of Posts and Telecommunications asked NTT to expand telecommunications facilities in Shangxi Province as an "urgent necessity". In response to this request, NTT expanded the transfer to Shangyinxian, Datongxian and Yangquan Offices.

Meanwhile, the construction of the testing room and the testing office, covering work ranging from foundations to installation tests, was begun in December, 1984 by the Third Construction Corporation of China's Ministry of Posts and Telecommunications. Chinese engineers faced and overcame one problem after another including NTT's construction methods entirely new to them. They completed the work one month earlier than scheduled, and celebrated the completion in a grand manner on 29 September 1985.

Areas Where NTT's Crossbar Switching Systems Were Introduced

NTT's switching systems were introduced as shown in Fig. 3 under the guidance and support of the Chinese Ministry of Posts and Telecommunications to the inland areas of the country, where were comparatively low in telephone density. The systems provided telephone services in these areas in a short time. The spread in service was particularly remarkable in Shangxi Province,



No. of lines	11	4	47	42	50	51	53	32	30	6	Total 326
Fiscal year	84	85	86	87	88	89	90	91	92	93	Fiscal yr
No. of units	4	3	21	19	18	25	42	25	17	3	Total 177

Figure 1. Facilities Transfer by Fiscal Year

Yunnan Province, and the Neimenggu Autonomous Region. Of these areas, Shangxi Province, the "testing province" for introducing NTT crossbar switching systems, is reported in "The People's Posts and Telecommunications" to have introduced the switching systems extensively from the neighborhood of Huanghe (on the Yellow River) in the south to the foot of Changcheng (at the Great Wall of China) in the north.

3. State of the Facilities Transfer by Province and Type

The transfer of facilities reached its peak in 1990, and is divided into three stages:

(1) the testing stage in 1984 and 1985;

(2) the up and running stage from 1986 to 1990;

(3) the transfer reduction stage from 1991 onward.

In the initial stage of transfer, most of the facilities were C400 crossbar systems for large-scale offices. In the later stages, transfer of expandable and transportable switching systems increased.

A breakdown by province/autonomous region of lines and units transferred is as shown in Fig. 4.

4. Technical Problems and Solutions (Development of Interfaces)

Local switching systems in service in China prior to the transfer were chiefly comprised of Chinese-made crossbar systems and step-by-step systems. For both local and toll offices, the inter-office signaling system was a Multi- Frequency-Code signaling system using a single frequency of 2,600 Hz for a line signal. Study and development of interfaces were required before introducing NTT's crossbar systems into the Chinese network.

As a result of various studies, NTT decided to add necessary interface functions to C82 (NTT's toll switch) switching systems because of the cost and time required to remodel C400 systems (Fig. 5).

5. Technology Transfer

For many years NTT has accumulated technologies for crossbar switching systems. NTT was required to

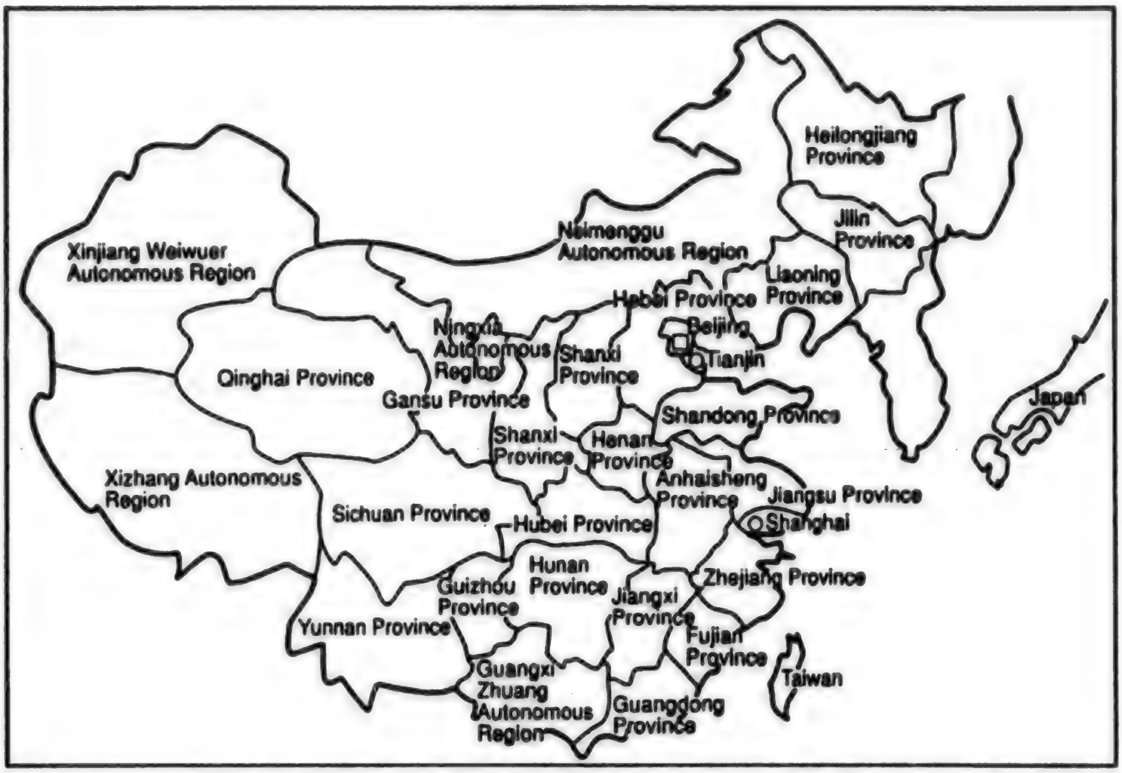


Figure 3. Areas Where NTT's Crossbar Switching Systems Were Introduced

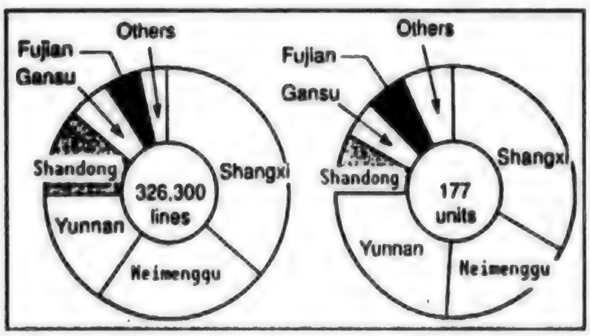


Figure 4. Breakdown by Province/Autonomous Region of Number of Lines and Units

transfer these technologies including those for construction and maintenance together with the transfer of facilities. To meet this requirement efficiently in a short period of time, NTT placed emphasis on the training of leaders, and made plans to have trainees witness NTT's operations in removing crossbar switching systems from service and receive necessary on-the-job training.

5.1 Transfer of Construction Technology

NTT dispatched engineers from Japan to give technical guidance directly to the Chinese engineers on site during construction of the transferred switching systems.

5.2 Transfer of Operation and Maintenance Technologies

Basic technologies required for maintenance were transferred to Chinese trainees while they were in Japan, and application technologies were given to Chinese operators through training sessions held at local sites.

6. Effects of Transfer

NTT's crossbar switching systems were put into service at a relatively low cost and in a short period of time. This helped enhance communications, thereby speeding up and invigorating business activities in China.

Shangxi Province's "Communications Technology" says that "NTT's switching systems are excellent in quality, low in failure rate, superior in performance, and capable of unattended operation, enabling a drastic reduction in maintenance personnel and operating costs."

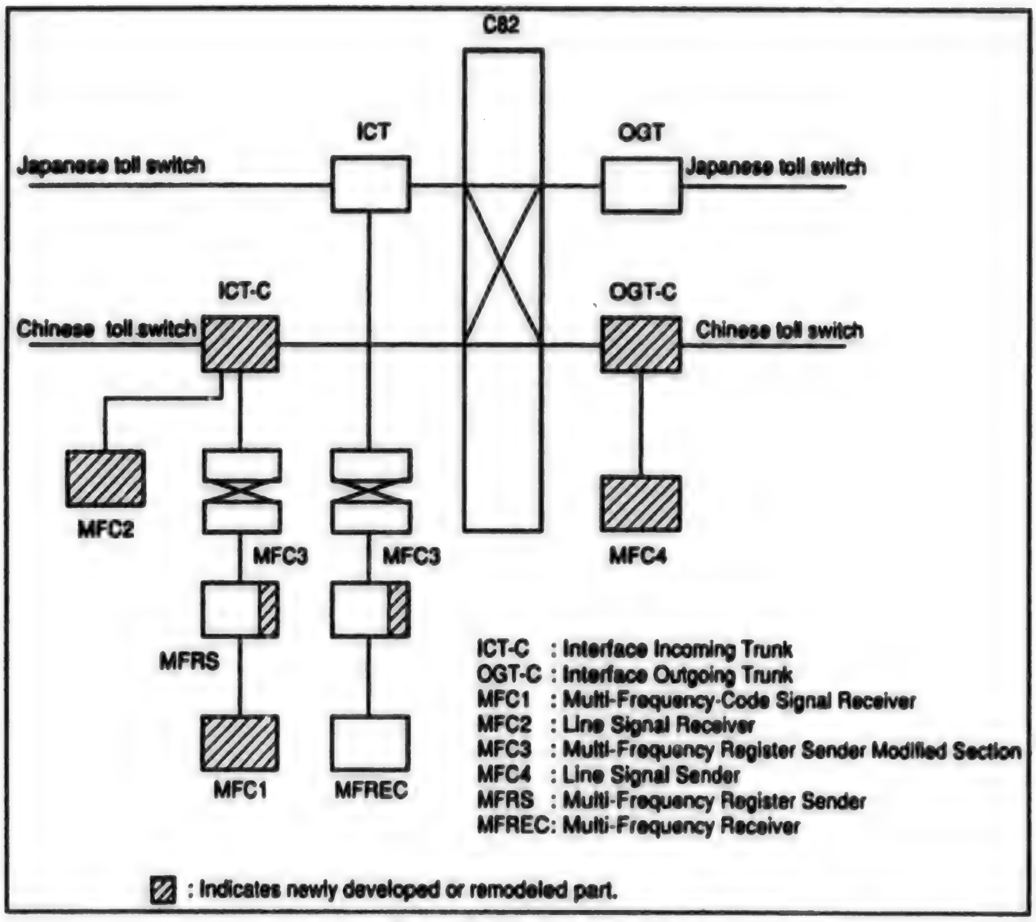


Figure 5. Interface Diagram

The number of lines made available by placing NTT-transferred switching systems into service exceeded 300,000 lines in 1992. To commemorate this occasion, Kunming City in Yunnan Province and Jinghjong Office jointly held a magnificent ceremony attended by representatives of the Chinese Ministry of Posts and Telecommunications, Autonomous Regions, Offices of Posts and Telecommunications, and NTT.

7. Development of Telecommunications Services in China

Telecommunications services in China have experienced great progress over the last 10 years, especially during the seventh five-year plan (1986 through 1990). At that time, the number of telephone sets in service alone achieved a dramatic level of increase, rising to three times the number in use ten years before.

The coming decade is an important period for the development of the Chinese economy. During this period, energy, transportation, and posts and telecommunications are expected to be treated as important issues, with telecommunications services seen as a vital business. NTT will therefore continue its efforts to contribute to the further development of Chinese telecommunications services.

Conclusion

The transfer of NTT's crossbar switching systems to China has helped expand the telecommunications network in China and promote China's modernization. It has also helped create a relationship of mutual confidence between NTT and the Chinese telecommunications community.

The successful transfer of the crossbar switching systems resulted from cooperation by numerous people in overcoming various technical problems, establishing rules of procurement and transportation, and carrying out technology transfer and construction work.

NTT is now expanding its business in China based on the close relationship of mutual confidence cultivated through this transfer. Together with our predecessors who took up the challenge of removing switching systems from service and transferring them across the ocean, and

those who participated in the transfer operation, we would like to express our gratitude for having had the opportunity to contribute to the promotion of friendly relations between Japan and China. We would also like to express our best wishes to China in the further development of its telecommunications services.

Multiple Digital Image Transmission System by Japan Satellite Systems

43070200B Tokyo SCIENCE & TECHNOLOGY in Japan in English May 94 p 69

[FBIS Transcribed Text] Japan Satellite Systems Inc. has succeeded in simultaneously transmitting four independent digital images by using its 27-MHz band transponder in combination with a 45-Mbps codec "MUCCS 45" and 8fPSK modem developed by Ikagami Tsushinki Co., Ltd.

Previously, the transmission of three independent digital images had been regarded as the limit through digitalization in the 27 MHz band, but the transmission of four independent images has been achieved in the 27 MHz band by introducing new technologies such as the 8fPSK modulation system. As a result, the new transmission system is compatible with the Space Communications Corporation (SCC) System for four-image transmission that is being commercialized using a 36 MHz band transponder. The new system will be commercialized after confirming the image quality during rain.

Compared with existing analog transmission systems, the digital transmission system uses the transponder most effectively. Since multiple independent images can be transmitted simultaneously with a single unit, the expensive transponder can be utilized at a low cost, so its commercialization is being advanced intensively.

The company succeeded in the 4-image transmission in the narrow bandwidth of 27 MHz due to the introduction of the 8fPSK modulator developed by Ikagami Tsushinki Co., Ltd. The 8fPSK modulation system had remained in the stage of technical development compared with the QPSK modulation system that is in wide use today for data transmission, but the two companies have now succeeded in commercializing the system.

The company has realized a 8fPSK modem with a Carrier to Noise Ratio comparable to that of a QPSK by introducing the trelis coded modulation system that combines error correction technology and modulation technology which had previously been applied independently.

Outline of Japanese Information Service Industry

43070200A Tokyo SCIENCE & TECHNOLOGY IN JAPAN in English May 94 pp 57-63

[Article by Akira Ogata of the Japan Information Service Industry Association (JISA)]

[FBIS Transcribed Text] About 30 years have passed since the Japanese information service (I.S.) industry emerged. During this period, the investments by private enterprises in information service expanded substantially in concert with the country's rapid economic growth, and the I.S. industry grew into a large-scale industry with a sales revenue of ¥7 trillion and a labor force of 500,000 employees.

During the last decade, the sales volume of the I.S. industry increased by 8 times with an average growth rate of 24%, which is a remarkable growth rate among all industries.

Characteristics of Japanese I.S. Industry

Information service in Japan has been advanced under various favorable conditions such as the protective language barrier, corporate practice of lifetime employment, versatile organizational setup and ample information service development budget, so unique information service systems were established independently by various enterprises in a characteristic Japanese fashion. As a result, the I.S. market was limited to within the country, and while there was no system obstacle, there was hardly any room for the participation of foreign information service enterprises.

Unlike in the United States, Japanese computer manufacturers' approach was to supply both of computer and software, so in the initial stage of I.S. industry development, software was considered of only a subsidiary value to be attached to hardware equipment. Therefore, the establishment of the value of software in the market was rather late compared with the United States.

A characteristic of the management of Japanese I.S. enterprises is that the ratio of labor cost to the sales volume is as high as 46% on the average, and that since many enterprises in the industry do not possess assets which can be valued as collaterals for bank loans, procurement of loans from commercial banks becomes difficult unless their corporate performances keeps excellent growth rate.

For software development servicing companies, which accounts for nearly one-half of the total I.S. market, it is the technologies of software engineers that make the base of their business and create added values. The information service industry is highly dependent on "human" factors. However, although financial institutions give the highest evaluation to real estate, they accept no collateral value as yet on software that is the product of highly advanced intellectual technology, so fund procurement on the basis of software products is quite difficult now.

Market and Services

Statistics for Assessing the Japanese Information Service Industry

Available as the statistics for assessing the state of the Japanese I.S. industry are the statistics provided by the

"Specific Information Service Industry Factual Survey" conducted annually by the Ministry of International Trade and Industry (MITI) from 1973 with the country's entire I.S. enterprises as the targets, and the statistics provided by the "Information Service Industry Basic Statistical Survey" conducted by the Japan Information Service Industry Association (JISA) with all its member enterprises as the targets. Virtually all influential information service enterprises are members of the JISA, specifically the association is the representative of over 600 companies belonging to the Japanese I.S. industry.

Based on the comparison of the results of these two surveys, the assessment from the sales revenues by types of services, sales revenues by types of users and number of employees are described here.

Overall Statistics (1): MITI's "Specific Information Service Industry Factual Survey" (Conducted in Nov. 1992, announced in Dec. 1993)

Annual sales revenue: ¥7,127.6 billion Number of employees: 488,469 workers Number of enterprises: 5,088 companies (Number of target business offices: 6,977 offices)

Overall Statistics (2): JISA's "Information Service Industry Basic Statistical Survey" (Conducted in June 1993, announced in March 1994)

Annual sales revenue: ¥4,260.4 billion Number of employees: 240,736 workers (Responding target enterprises: 455 companies)

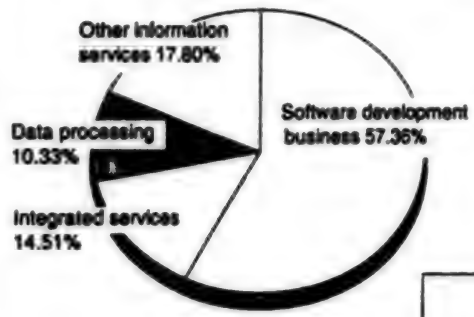
The 455 JISA member companies responding to the Information Service Industry Basic Statistical Survey account for only 8.9% of the total number of I.S. enterprises in the country, but they account for about 60% of the trade's total annual sales revenues, and for about 50% of the total number of employees, indicating that JISA is actually the organization representing the Japanese information service industry.

Table 1. Transition in Annual Sales Revenues by Business Sectors

Classification	1990			1991			1992		
	Gain over Year Before (1 Million)	Annual Sales Volume (%)	Constituent Ratio (%)	Gain over Year Before (1 Million)	Annual Sales Volume (%)	Constituent Ratio (%)	Gain over Year Before (1 Million)	Annual Sales Volume (%)	Constituent Ratio (%)
Total	5,872,678	100.00	35.0	7,039,659	100.0	19.9	7,127,618	100.0	1.2
Consigned computing	963,333	16.4	29.3	1,094,800	15.6	13.6	1,100,128	15.4	0.5
Software development/program drafting	3,457,947	58.9	37.6	4,301,045	61.1	24.4	4,295,891	60.3	0.1
Keypunching & other data processing	204,358	3.5	22.8	209,607	3.0	2.6	201,178	2.8	4.0
Machine time-selling	53,628	0.9	37.4	59,217	0.8	10.4	47,212	0.7	20.3
System control & operation under consignment	275,830	4.7	28.5	308,837	4.4	12.0	363,394	5.1	17.7
Data base service	188,613	3.2	19.7	215,981	3.1	14.5	214,064	3.0	0.9
Various types of surveys	260,935	4.4	27.8	313,731	4.5	20.2	277,238	3.9	11.6
Others	468,029	8.0	50.1	536,443	7.6	14.6	628,511	8.8	17.2

According to MITI's "Specific Information Service Industry Factual Survey," the annual sales revenue of the Japanese I.S. industry in 1992 ran up to ¥7,127.6 billion, a slight gain of 1.2% over the preceding year. This was the lowest growth rate since 1973 when this survey was started. The Japanese I.S. industry had continued to register big gains, supported by active information service corporate investments during the last several years due to the bullish prosperity. The growth rates over the preceding years were 43.4% in 1988, 32.0% in 1989, and 35.0% in 1990. The growth rate dropped to 19.9% in 1991, but positive growth continued. However, in 1992, the domestic prosperity came to a halt through the

Table 2. Breakdown of Industry by Types of Services



	Number of Enterprises	Constituent Ratio (%)
Integrated services	66	14.51
Software development	261	57.36
Data processing	47	10.33
Other services	81	17.80

so-called bubble economy burst, which led to a suppression of I.S. investments as well as a freezing of new I.S. investments by industry as a whole including the main users of I.S. such as the financing, insurance and manufacturing industries. The I.S. industry sales revenue growth rate dropped to an extremely low level of 1.2% compared with the preceding year.

MITI's "Specific Information Service Industry Factual Survey"

According to the "Information Service Industry Basic Statistical Survey" conducted by JISA, the total annual sales revenues of the 455 responding enterprises ran up to ¥4,260.4 billion, giving an average sales volume of ¥9.4 billion per enterprise. In this JISA survey, the classification of types of businesses differs slightly with that of the MITI survey. Described next are the sales volumes by the main types of businesses, based on the JISA survey.

1) Integrated Service

The term integrated service under this classification of business types is the integrated system services offered in response to client requests, which includes the entire series of operations from system development planning and design to software development, and also includes system operation and maintenance.

Today, many Japanese I.S. enterprises are striving to become integrated service type enterprises. When it becomes possible for I.S. enterprises to undertake user businesses as system integrators, there will be no need for the user to maintain a system department within its company, nor to retain system personnel. This may be desirable for the user, but it is certain that I.S. enterprises will be faced with stiffer demands and that user's selection of I.S. enterprises to deal with will become much more rigid. I.S. enterprises will be undertaking integrated system service in response to client requests over a long period of time, which include the entire series of operations from system development planning and design to software development, including system operation and maintenance, so it will be necessary for these enterprises to accumulate an ample financial potential, foster a capability for the development of sophisticated technologies and maintain a team of talented information processing engineers. Namely, it will be an arena for testing the real strengths of I.S. enterprises, or their capability to come out rapidly with technological innovation as well as to cope flexibly with the sophistication and diversification of user needs.

Among the 455 enterprises responding in the JISA survey, there were 66 integrated service enterprises which accounted for 14.5% of the total respondents. Their total sales revenues for FY 1992 ran up to ¥829.3 billion, 19.5% of the total sales volume of the entire industry, and registering an increase of 4.5% compared with the preceding year.

2) Software Development

Included in software development are consigned software development by user, and software product development/sale for general market. Software development grew into a primary business sector of the I.S. industry, supported by the continued increases of corporate I.S. investments during the last dozen years or so. However, the industry was hard hit by the so-called bubble economy burst, which triggered a suppression of investments as well as a freezing of new information service investments.

In FY 1992, the sales of software development under consignment ran up to ¥1,324.3 billion, and software market product to ¥76.7 billion. The combined sum accounted for 32.9% of the I.S. industry's total sales

volume of ¥4,260.4 billion, indicating that this sector still accounts for the main sources of revenues of the I.S. industry. However, consigned software development suffered a drop of 5.5% compared with the preceding year while software market product dropped by 2.9%.

3) Consigned Computing Service

The sales of this service in FY92 ran up to ¥761.9 billion, accounting for 17.9% of the I.S. industry total sales revenues and registering a growth rate of 0.3% over the preceding year.

In Japan, the consigned computing service has been divided all along into on-line processing and batch processing, and on-line processing further into VAN and on-line consigned computing services. However, in concert with the establishment of data transmission networks, the reliance on information service steadily spread to the entire industrial world and, due to user diversification, the consigned computing service market is certain to shift further to information communications services primarily involving the VAN service.

To grasp these trends accurately, in the JISA survey, statistical figures were obtained by separating the network service from the conventional consigned computing service. According to these figures, the sales volume of the network service ran up to ¥87.4 billion, comprising as yet only 2.1% of the total sales, but the growth rate was 5.1% over the preceding year, indicating a sound growth rate.

Transition of Sales Volume by Users

Table 3 shows the breakdown of the annual sales volume of ¥426.04 billion of the 455 enterprises responding to the JISA survey by types of users (contracting industries).

Table 3. Breakdown of Sales Volume by Types of Service

	1991			1992			
	Annual Sales Volume		Constituent Ratio (%)	Annual Sales Volume		Constituent Ratio (%)	Gain over Year Before
	(¥1 Million)	(¥1 Million)		(¥1 Million)	(¥1 Million)		
Total information service	3,539,433	7,779	81.83	3,512,826	7,720	82.45	-0.75
Integrated service	793,499	1,744	18.34	829,253	1,823	19.46	4.51
(Hardware-related)	(87,055)	(191)	(2.01)	(81,996)	(180)	(1.92)	-5.81
Software development	1,401,287	3,080	32.40	1,324,329	2,911	31.08	-5.49
Network service	78,997	174	1.83	76,736	169	1.80	-2.86
Software product development & sale	760,003	1,670	17.57	761,901	1,675	17.88	0.25
Computing service under consignment	83,235	183	1.92	87,476	192	2.05	5.10
Other services	422,412	928	9.77	433,131	952	10.17	2.54
Hardware-related	578,158	1,271	13.37	538,228	1,183	12.63	-6.91
Others	207,857	457	4.81	209,303	460	4.91	0.70
Total	4,325,448	9,506	100.00	4,260,357	9,363	100.00	-1.50

JISA's "Information Service Industry Basic Statistical Survey"

Classifying the types of clients broadly into general users, trade enterprises and computer manufacturers, the sales volumes are ¥327.53 billion for general users, ¥379.1 billion for trade enterprises and ¥606.0 billion for computer manufacturers. The general situation is that the sales to general users accounts for 76.9% of the total sales volume, but a closer study shows that the manufacturing industry accounts for the highest ratio of 21.2% of the total sales, the service industry for 21.0%, the financial industry for 17.0%, others for 9.8% and governmental organizations for 7.9%. The figures also show that the sale to governmental organizations increased by 6.5% over the preceding year and the service industry by 6.1%, and others by 8.6%, indicating sound increases while the manufacturing industry registered a decrease of 6.7% and the financial industry of 4.7%.

Table 4. Breakdown of Sales Volume by Types of Clients

	1991			1992			
	Annual Sales Volume		Ratio (%)	Annual Sales Volume		Ratio (%)	Growth Rate (%)
	(1 Million)	(1 Million)		(1 Million)	(1 Million)		
General users	3,271,039	7,189	75.62	3,275,252	7,198	76.88	0.13
Financial industry	760,957	1,672	17.59	725,017	1,593	17.02	-4.72
Service industry	841,249	1,849	19.45	892,468	1,961	20.95	6.09
Manufacturing industry	967,170	2,126	22.36	902,615	1,984	21.19	-6.67
Governmental organizations	316,924	697	7.33	337,537	742	7.92	6.50
Others	384,739	846	8.89	417,615	918	9.80	8.55
Trade enterprises	391,798	861	9.06	379,115	833	8.90	-3.24
Computer manufacturers	662,611	1,456	15.32	605,990	1,332	14.22	-8.55
Total	4,325,448	9,506	100.00	4,260,357	9,363	100.00	-1.50

For the I.S. industry in Japan, the major users are the financial, securities, insurance and manufacturing industries. These major users have been hard hit by the economic recession, triggering a suppression of information service investments or a freeze of investments for the development of new systems as mentioned above. In addition, the computer manufacturers themselves have decreased their orders to the I.S. industry due to the stagnant sales, with the result that the growth rate has slumped by as much as 8.6%. Therefore, the I.S. industry enterprises in Japan is faced with the difficulties caused by economic recession, and also with the need to cope with changes caused by technological innovation.

Information Service Industry Technology

(1) Work Items for Product Development and Related Engineers

When users consign the work of establishing an information processing system to an I.S. enterprise, several problems frequently encountered are:

(i) The technical personnel of the I.S. enterprise are incapable of keeping up with the rapid progress of computer technologies, sophistication of system development technologies and wide-area servicing of networks.

(ii) The intensified competition with other enterprises in the fabrication of I.S. systems.

(iii) The need for a drastic reassessment of development and operating costs of the I.S. systems.

In order to respond adequately to the expectations of users, it will be necessary for I.S. enterprises, as the specialized developers of information service systems, to provide merits to users, such as shorter time for product development, superior quality at the same cost, or lower cost maintaining the same quality.

However, as the I.S. industry products are invisible to users, it is quite difficult to assess the cost of development. Also, in actual product development, contracts are sometimes concluded before the specific details of the target business, quality level or function level are clarified, leaving the limits of responsibilities between the contracting parties uncertain. Therefore, specifications tend to be changed frequently subsequent to the commencement of system development, which becomes a cause of troubles and adversely influences the product price and delivery schedule.

These problems in transaction can be avoided by establishing the following:

(i) Standard work items for development by the trade.

(ii) Standards for assessing the qualifications of system development engineers.

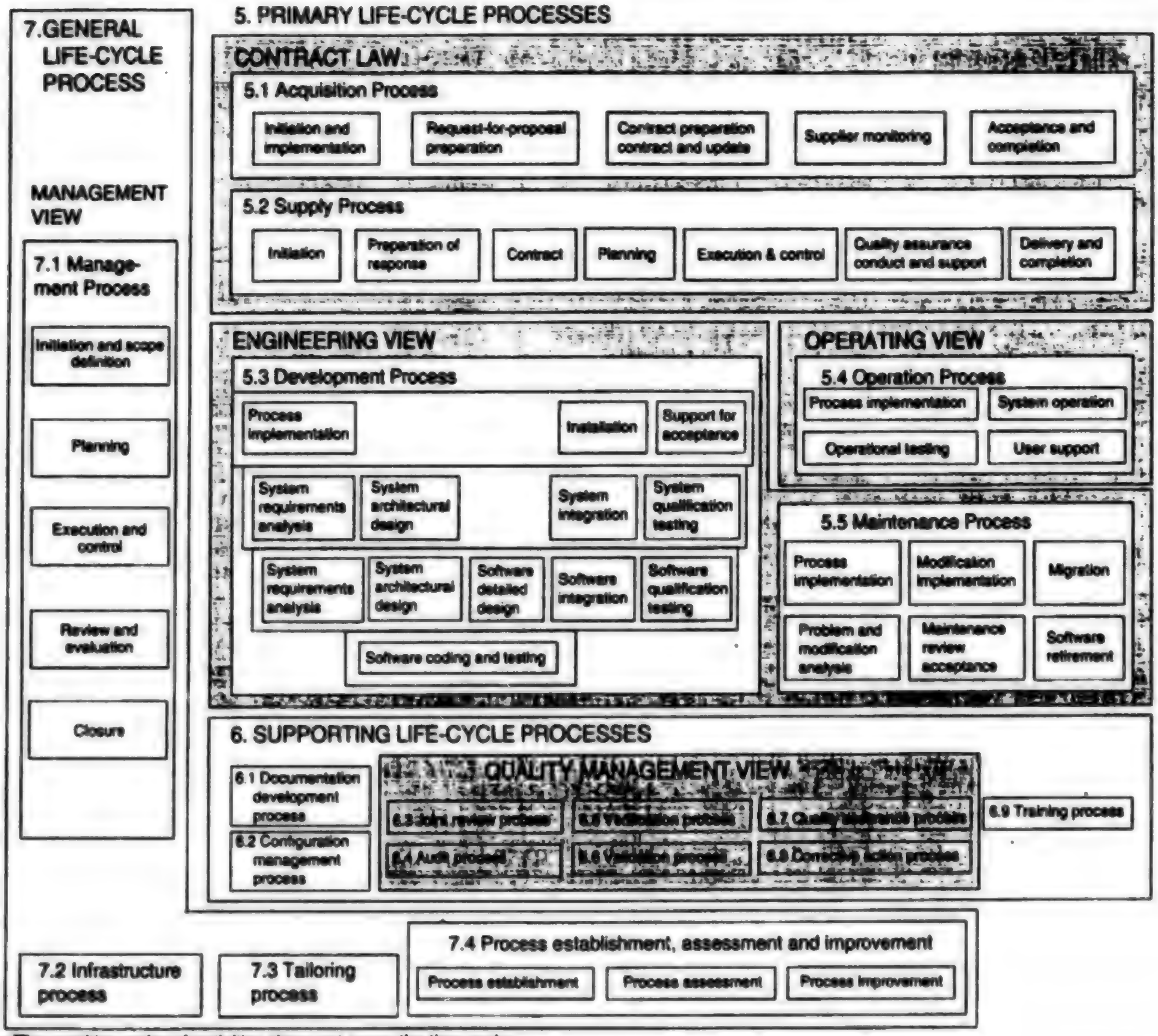
Namely, it is required to establish a clearer clarification of the contents of transactions, a system which enables the product quality reflected on the price, and a market for users to freely select any specific I.S. enterprise.

1) Work Items for Product Development

Regarding the standard work items for product development, a common frame (see Fig. 1) was established in March 1994 with the cooperation of the I.S. industry, users, computer manufacturers and academical circle, based on the ISO/IEC software life cycle process (SLCP).

In designing the common frame, to make the I.S. system applicable to actual business operations, all operations for system development, operation, maintenance and further for the disposal of obsolete systems, were first

Software Life-Cycle Processes, Views and Activities



*The position order of activities dose not mean the time order.
Names of activities in the development process are not names of development phase.

classified and regulated from the initial stage of planning, based on the concept of (a) independence, (b) coexistence and (c) consistency in the development systems and methodologies of each company.

Next, systematization was made in the process group (procurement process and supply process) of the contracting work that defines the flow of contract between the procurer and supplier in the bipartite transaction, and the process group (basic process group and ordinary process group) relating to the system development work that is the target of contract.

The process was further sub-divided into activities (which subdivide the work within a process of each work objective), and into tasks (the individual tasks for concretely carrying out or supporting the activities).

2) Engineers

The "quality" of information service systems is largely characterized by the user "efficacy," so its evaluation is extremely difficult. Therefore, it will be vital to clarify the technological levels of related engineers for use in place of the quality evaluation standard.

However, it will be quite difficult for conventional engineers and programmers to perform the sophisticated and diversified functions demanded by future systems. In this connection, the Information Service-Oriented Personnel Deliberation Committee of the Ministry of International Trade and Industry announced in December 1992 the necessity of fostering talented personnel possessing ample experience and sophisticated specialized knowledge specifically for the following nine specialized fields.

(i) System Analyst

The role of this analyst is to plan and draft integrated information service systems such as total corporate information service systems and large-scale social systems from the perspective of management strategy, also to perform system monitoring in general in connection with information system planning, designing, fabrication, maintenance and operation.

(ii) Application Engineer

The roles are the planning, analysis and basic designing of individual applied systems such as applied business application and applied engineering systems.

(iii) Production Engineer

Coordinated system fabrication operations from designing to programming and testing.

(iv) Project Manager

Administration of the entire information service system fabrication project, including the operations of estimation, scheduling, quality control, process control and personnel administration.

(v) Technical Specialist

A specialist for maintaining system components in their optimum conditions, such as hardware, software, data bases and communications networks, as well as for offering technical support to other engineers. On the supplier side, he offers technical consultation to user enterprises.

(vi) System Operation and Control Engineer

A specialist for the operation and control of information service systems including communications networks.

(vii) Development Engineer

To develop system software, advanced software packages and products incorporating microcomputers.

(viii) Education Engineer

This engineer engages in education planning, education material development and the evaluation and administration of education systems, for internal and external specialized engineers and end users.

(ix) System Administrator

This administrator is the leader in information service systems for end users, and performs the roles of technical guidance of end users and maintenance of interface with suppliers.

It is also necessary to establish a curriculum and, at the same time, an appropriate system for evaluating the results of education, so a standard curriculum conforming to the new classification of engineers was drafted by the Central Information Education Institute of the Japan Information Processing Development Association. Up till now, information processing engineer tests used to be conducted with emphasis placed on popularizing information processing technologies, but from now on, tests are to be conducted in conformance with the new engineer classification system and the new curriculum.

As a result, a system has been established for engineers mastering the curriculum to pass the test, and it has become possible to adopt the new information processing engineers test as an objective standard for assessing engineers.

(2) Technology Classification

The method of solving transaction problems, as observed from the technological aspect, is to find solutions by substantiating the environments relating to developmental work items and engineers. For this, it will be necessary to see what kinds of technologies are available for supporting both work items and engineers, and to ascertain how they are classified.

The technologies necessary for the I.S. industry extend over a broad area and undergo rapid changes, so their systematization will be quite difficult. To enable engineers to smoothly execute the respective processes prescribed by the common frame, it would be convenient to classify and rearrange related technologies, such as the analysis technologies necessary for the product planning and designing operations, the manufacturing technologies necessary for product development, the operational technologies necessary for system operation, and the elementary technologies supporting these various technologies.

1) Analysis Technology

This is a technological sector for drafting consulting technologies as for survey analysis and problem discovery and solution after acquiring a good understanding of the user's trade and type of business, as well as for drafting the optimum systematization plans matched to user needs by referring to his trade and business knowledge. Naturally, a broad scope of knowledge will be necessary as in connection with economy, laws and science.

2) Manufacturing Technology

The manufacturing technology is fundamental to the I.S. industry, and essentially consists of the manufacturing technology and the control technology.

The system whose essential parts have been designed is developed by programming its diverse processing procedures and incorporating it with diverse elementary technologies. But in order for it to respond to the user demands as in connection with quality, delivery schedule and costs, it will be necessary to consolidate the developmental environment incorporating the necessary manufacturing technology.

The manufacturing technology includes development support tools such as CASE as well as the technologies for the reutilization of software components, and both productivity and quality can be improved by applying the manufacturing technology in combination with control technologies such as project control technology.

3) Operation Technology

The system delivered to the user upon its development and completion may be similar to the system in operation at the company's computer center, but the more the system's importance increases, the user's evaluation of the system will be greater, depending on how efficiently it can be operated and on how well it can meet his needs.

The operation technology for system maintenance and control involves technologies for resources control, network control, system monitoring and maintenance.

4) Elementary Technology

The elementary technology refers to technologies which are necessary for fabricating optimum systems meeting the user needs, and can be classified into those relating to hardware, software, network and applied technologies.

Hardware includes versatility machines to those for workstations, input/output terminals and private branch-exchanges. Meanwhile, network includes the integrated services digital network (ISDN), mobile communications network and others. Applied technologies include artificial intelligence (AI), object orientation and MMI, or technologies for improving system functions and ease of use.

Structural Changes in I.S. Industry

Structural changes are taking place in the I.S. industry in Japan today.

(1) Structural Change in Technologies

The first structural change concerns the sector of technologies. The conventional types of computer and software technologies consist primarily of technologies relating to large-capacity computers like those fabricated by IBM and their applied technologies.

However, more recently, the downsizing trend is in progress and the method has emerged of fabricating information servicing systems by linking compact computers in a network. In the sector of software, they used to be created by using computer languages such as the conventional COBOL language, but in the downsized system, an entirely different type of computer language is used.

Also, when fabricating the conventional type of information service system, the conventional concept used to regard the large-capacity computer as the "host," but in the new concept, the part using terminal computers is regarded as the "host," making it necessary to introduce new technologies involving network technologies.

As a result, a major trend in the information service industry is to reeducate software engineers to enable them to work in the downsizing market that is expected to undergo conspicuous expansion into the future.

(2) Structural Change in Market

In the age of large-capacity computers, the sources of information service investments were the corporate information service systems departments whose personnel were computer experts. However, in the downsizing or end user computing age, the main users have shifted from specialized computer operators to novice business personnel, clerks in general and managers, with the result that the targets and methods of business activities are undergoing a change.

Also, differing from the age of Japan's high rate of economic growth when business funds were ample, the country now lies in a state of recession that dictates rigid checking of the effects of investments in information service systems, so the trend is to postpone new I.S. system development and introduction plans. In addition, when information service systems become massive in scale and become linked to network system inside and outside the corporation, it will become difficult to make a quantitative assessment of the effects prior to and after a system introduction, which is a major factor obstructing investments in new information service systems.

(3) Structural Change in Information Service Industry

Downsizing does not simply mean miniaturization of the computer but also refers to cost miniaturization, or price reduction. The computer manufacturer, in concert with the progress of downsizing, is becoming incapable of seeking high added values in hardware, and coming to pursue high added values in the sectors of software, consulting and related businesses. Namely, an "information service industrialization" move is proceeding among computer manufacturers.

In addition, when the multimedia market is established, information servicing will be introduced into various sectors of industry such as broadcasting, movies, publishing, news reporting and home electrical appliances, and a fierce competition may be waged in the information servicing market.

When the information service industry achieves expansion by hurdling the existing obstacles, various services and enterprises of diversified forms will create a massive information service industry.

For the I.S. enterprises in the new age, innovative technologies and new management concepts as well as strategic marketing approach are required.

Future Outlook of I.S. Industry

The Japanese information service industry is presently faced with a stringent state due to the recessive domestic economy, but this does not mean that the entire industry

is stagnant. Polarization is taking place, and enterprises coping flexibly with new technological and market changes are continuing to grow steadily.

Comparatively underdeveloped I.S. market in Japan are the sectors of administrative organizations and educational institutes. Japanese government has announced its policy of striving actively to promote electronization of administrative procedures, establishment of a data base for administrative information and the establishment of a network of administrative organizations, so the information servicing of administrative organizations appears quite promising as a market for the I.S. industry in the near future.

Japanese information servicing, which has developed primarily with large-scale enterprises all along, is about to be expanded on the full scale to small- and medium-scale enterprises as an effect of the progress in downsizing.

Today, business process reengineering (BPR) is a major theme, but this business innovation method that created a boom in the United States is an element that is indispensable for supporting the modem information servicing technology. Even in Japan, the number of enterprises introducing the BPR technology as a recession breakthrough remedy is increasing rapidly, but the progress in BPR is simultaneously triggering a restructuring of the information servicing system, which is anticipated as a new information servicing move in the sector of large enterprises.

Also, in the "multibillion dollar" multimedia market, whose linkage to the I.S. industry is not fully clarified yet, information service industry is expected to play an important role in the field of middle software to support most of the multimedia areas such as communications, hardware, operating systems and multimedia products.

Mad Rush to Enter ATM LAN Business: More than 10 Firms Struggle in Fierce Battle

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[FBIS Translated Text]

[Abstract] In 1995 the number of makers selling chip sets for the ATM (asynchronous transfer mode) LAN (local area network) will exceed ten. First, it will be widely used for the network for a concurrent development. Each LSI maker will select and incorporate onto the LSI three types of ingenuities which will enable them to lower the system cost in order to promote its wide-spread use. One of them would be to narrow down the specifications to their bare essentials for LAN, whereby the number of gates loaded on the chip will be reduced. The second would be to incorporate peripheral circuits into the chip whereby the number of parts on the board will be reduced. The third will be to load the circuit enabling the utilization of the existing transmission route. This will achieve the cost reduction for the building of a network system.

There is a parade of LSI makers ready to unload even before the end of the year the chip sets enabling them to lower the price on the terminals of the LAN system utilizing ATM1. This is due to their further understanding that its application to the computer network which can realize a concurrent development environment acts as the fuse for its pervasive use. Further, the condition for ATM LAN to expand lies in the low cost of the system.

To that end, LSI makers incorporate into the chip set some ingenuities to lower the system cost. There are three categories to this:

1) lowering the price on the LSI by down-sizing the gate;

2) lowering the price on the board by integrating the peripheral circuits on the LSI;

3) lowering the cost of employing the system by loading on board the circuit which enables the transmission route of the existing system to be used (Fig. 3, not reproduced).

Rush by More than 10 Companies

It is predicted that the number of domestic as well as foreign makers unloading such chip sets will exceed ten in 1995. Following TranSwitch Corp. of the United States and PMC-Sierra, Inc. of Canada which started unloading them last year, NEC, Fujitsu, and Mitsubishi Electric for domestic companies and National Semiconductor Corp. (NSC), Texas Instruments Inc. (TI), and LSI Logic Corp. for U.S. companies have concrete shipping plans in place. In addition to these companies, IBM Corp. and Hewlett-Packard Co. along with Oki Electric Industries and Motorola Inc. of the United States are discussing the commercialization of them.

It had at one time been thought that its real wide-spread use would be around the year 2,000, but as of now that has greatly been pushed forward. The view held by NSC or TI that the user of LAN has begun to require the concurrent development environment requiring a transmission capacity of an excess of 100 Mbps (bits/sec.) is beginning to become the common acknowledgement. There is nothing other than ATM that can realize the transmission in the excess of 100 Mbps. It is said that in a concurrent development in which the products are developed by referring to CAD and the data for the production technology there arises a need for an instantaneous transmission of the data of some 100 M bits (TI). As soon as an interface circuit adapting to a computer's bus is loaded on board and a transmission route is secured, a network system can be built. TI predicts that the market for those solely intended for terminals alone will grow to that of some tens of billions of yen a year in 1998.

Necessary Condition for Its Wide-Spread Use Is Low Cost.

A condition for the wide-spread use of ATM LAN lies, first of all, in the "low cost of the board including the reduction in price on the LSI" (Japan TI). NSC, experienced in the LSI for Ethernet LAN, and TI, supplying chips to Sun Microsystems Inc. of the United States which has started the sales of ATM boards, observe that the condition for its wide-spread use is for the price on the board to fall below 10% of the computer itself.

Next, some measures enabling to lower the price on the network system are also incorporated into the LSI. "We will have the user shift to ATM with a small investment by loading a circuit whereby a transmission route can be shared along with Ethernet," say NEC and others.

The Lowering of the Price on the LSI by Narrowing Down the Functions.

The lowering of the price on the LSI described in (1) in the opening is achieved by narrowing down the protocols for the ATM being adapted to and the transmission frame. Of the ATM protocols, "AAL 1" and "AAL 2" are suited for the transmission of data such as animations. "AAL 3" and "AAL 4" are suited for public network while "AAL 5" for the data transmission for LAN.

The companies such as NEC, Mitsubishi, and Oki Electric adapted solely to AAL 5. By this, "20 - 30 thousand gates can be eliminated" (NEC). As a full-fledged arrangement for a public network is to be made after the year 2,000, it was judged that there is no need to be concerned with AAL 3 or 4 (NEC, Mitsubishi, and others).

In adapting to pictures and sounds, there are makers that are "studying the feasibility of AAL 5 being able to handle in 1995 the compressed animation data by MPEG" (NEC). However, the number of gates will increase if multiple AALs are adapted to simply by the hardware logic. LSI Logic solved it by loading on the chip RISC processor "R 3,000" as it is and processing AALs with the software. There are many makers that are "waiting for the arrival of AAL 6, based on AAL 5, with the specifications to be able to handle animations" (Oki Electric, Fujitsu, etc.).

As for the transmission frame, NEC, TI, and others narrowed down on the specifications "SONET" for the U. S. broadband ISDN. This "reduces" the size of the gate by "about one half" in comparison to NTT's circuit for the broadband ISDN (NEC).

Lowering the Price on the Board by Loading the Peripheral Functions

The lowering of the price on the board in (2) can be achieved by integrating the following three circuits. Those are: (a) DMA controller[2]; (b) Interface circuit for computer buses such as PCI and Sbuses; (c) clock recovery circuit and clock generating circuit which separate the signals attenuated along the transmission route into data and clock.

NEC, Fujitsu, LSI Logic and others have (a) on board. With this the main memory and data can be handled without going through the computer's main MPU. Many makers consider it important that the circuit structure does not burden MPU (Fujitsu). (b) is a measure used by TI and Mitsubishi. TI, as they were affiliated with Sun in the development of ATM technology, narrowed down on SBus. Mitsubishi deals with PCI bus used by the computer by DEC (Digital Equipment Corp.) of the United States. However, having the circuit adaptable to a specific bus on board limits the systems that are usable. For this, other makers do away with the circuit adaptable to a specific bus. TI and PMC-Sierra have adapted to (c). It is noted that this circuit integration lowers the price by 6,000 yen per system (Japan TI). In loading a circuit such as clock recovery circuit on board, "efforts to not let the noises from the digital circuit enter into the clock type analogue circuit are necessary" (Japan TI).

Lowering the Price on the System by an Existing Transmission Route

Lowering the price at the system's level described in (3) can be realized by improving from the current optical fiber adaptation to unshielded twisted pairs[3] adaptation. NSC and NEC will meet at the end of 1994 and after 1995 respectively the "UTP 5" specifications which are at the present being widely installed in the U.S. There already exists "UTP 3" specifications installed for the unshielded twisted pairs, but there is no maker adapting to this. It is because the size of the LSI gate would be doubled or tripled and it is expected that the installation cases for UTP 3 will be less frequent. (Motoaki Ito)

Footnotes

1. Asynchronous transfer mode. A method of transmitting the data by breading up into the fixed-length cells of 53 bytes (48 bytes for the data for the computer, and 5n bytes for the header). With a high bit rate of more than 100 Mbps, different kinds of data such as animations, voice, and letters can be transmitted through the same transmission route. Communications methods by the synchronous transfer mode such as Ethernet have yet to establish the transmission of more than 100 Mbps, and there is much waste in transmitting different kinds of data. Further, it is observed that ATM would initially be drawn to LAN application, but that it will in the future expand to the information super-highway and CTAV.

2. Direct memory access controller. A circuit transmitting the data between the memories or between the memory and the input-output device within the computer without going through the MPU.

3. A transmission route of copper wire used by the existing LAN such as Ethernet. Two types, namely, "UTP 3" suited for a transmission of some tens of Mbps and "UTP 5" enabling a transmission of more than 100 Mbps, are largely employed. Recently in countries such as the United States, there are more cases wherein a transmission route conforming to UTP 5 is built.

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